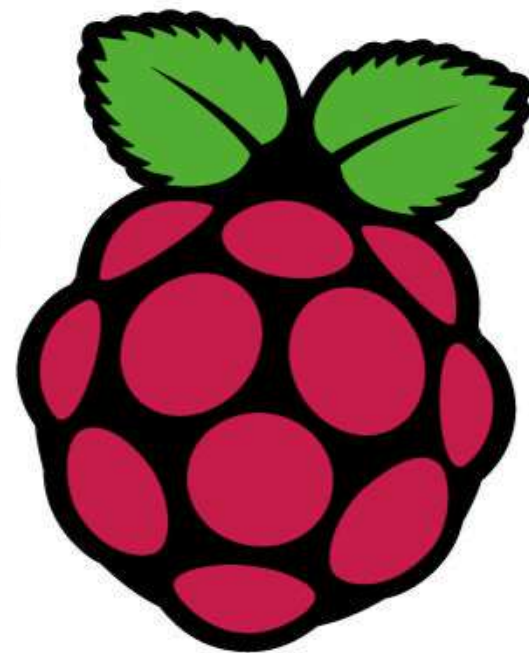




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# The MagPi



Issue 112 | December 2021 | [magpi.cc](https://magpi.cc)

The official Raspberry Pi magazine

**TOP 10 LEGO  
PROJECTS**

# MAKE & BUILD WITH ZERO 2

RASPBERRY PI  
**CHRISTMAS  
PROJECTS**

**+** **OVERCLOCK**  
RASPBERRY PI ZERO 2 W



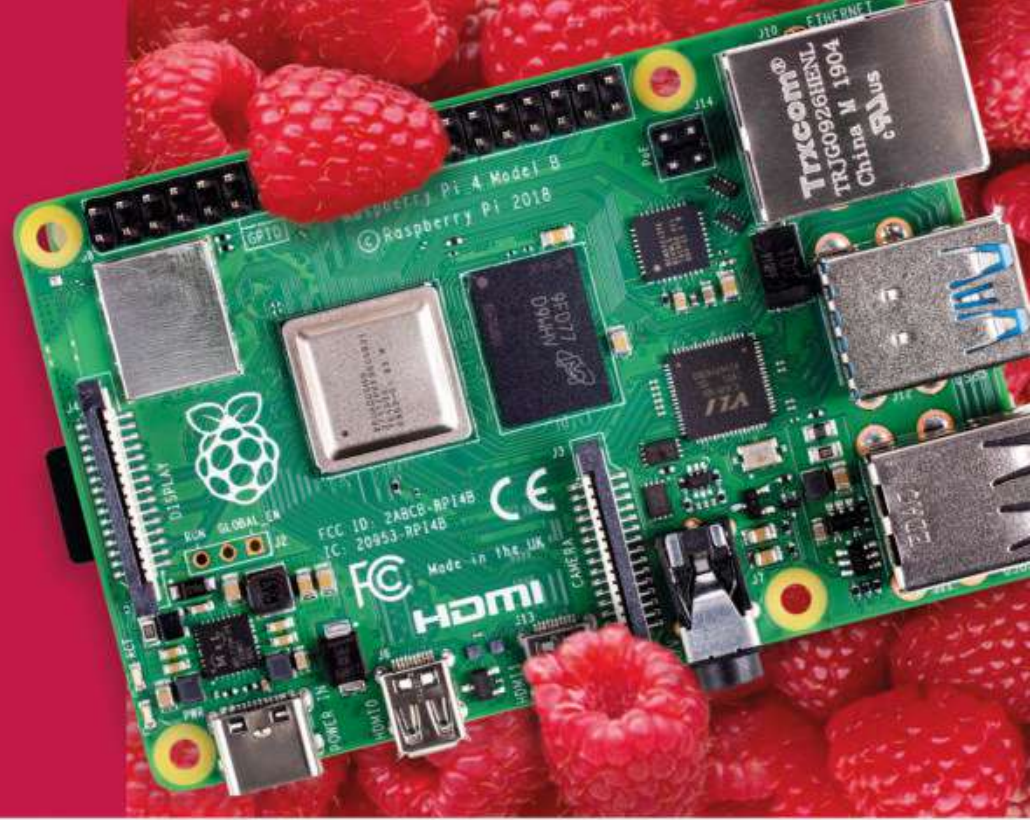
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# WELCOME

## to *The MagPi* 112

I'm a big fan of inquisitive people. Especially when it comes to messing around inside computers. After all, being inquisitive about computers is a big part of the Raspberry Pi experience.

I've just spent the last couple of days overclocking the Raspberry Pi Zero 2 W computer (page 52). With a cooling case and a couple of lines of code; an intrepid editor can get it running from 1GHz to 1.4GHz. A pretty nifty upgrade.

Zero 2 W is an incredible new computer. We've scoured every project from the last couple of years that involved Raspberry Pi Zero. The result is 40 incredible projects in our Make & Build with Zero 2 (page 34).

The last twelve months have been a wild ride on *The MagPi* magazine. We've had Raspberry Pi 400, Raspberry Pi Pico, and Raspberry Pi Zero 2 W. All incredibly different and interesting products that help us understand computers a little better.

As we head into the end of the year, few members of the team get excited about winter as much as Rob. His Raspberry Pi Christmas feature (page 63) is packed with projects for the festive season.

Merry Christmas and stay inquisitive.

**Lucy Hattersley** Editor



**EDITOR** Lucy Hattersley

Lucy is editor of *The MagPi* and she's using hot-water bottles and a cat to keep warm. Not sure either would benefit from Raspberry Pi Zero 2 W, but she's open to suggestions.

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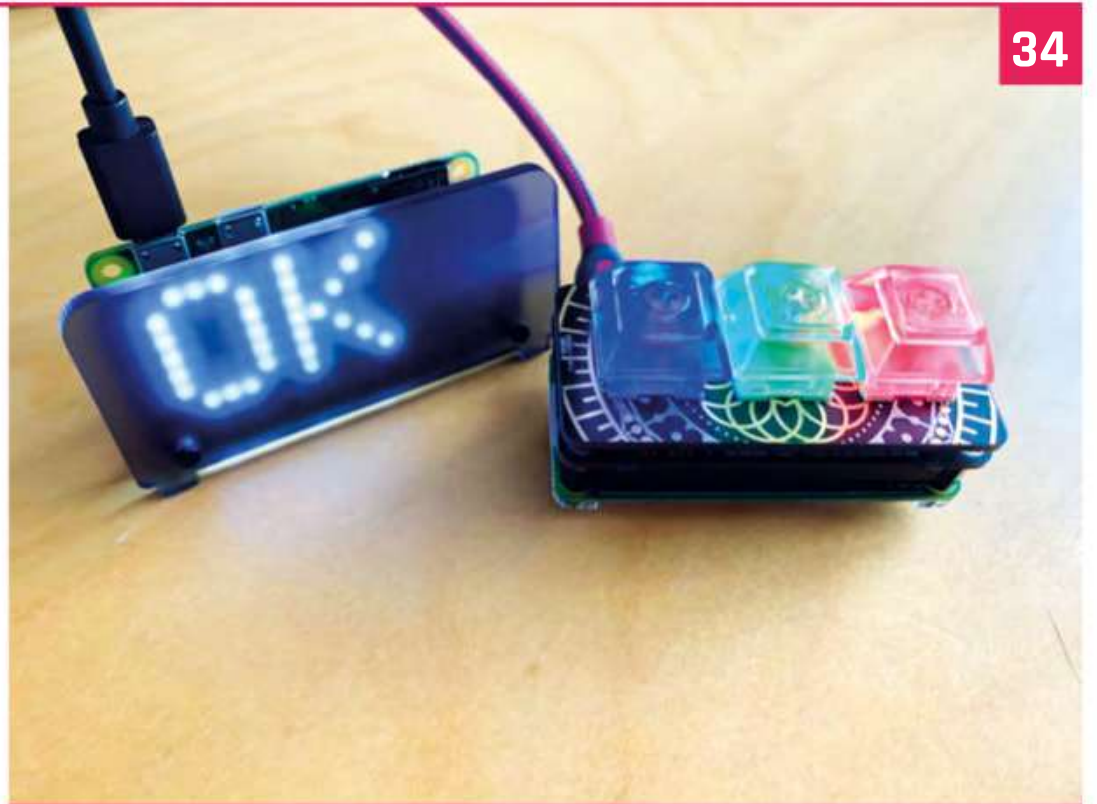
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**DISCLAIMER:** Some of the tools and techniques shown in The MagPi magazine are dangerous unless used with skill, experience, and appropriate personal protection equipment. While we attempt to guide the reader, ultimately you are responsible for your own safety and understanding the limits of yourself and your equipment. Children should be supervised. Raspberry Pi Ltd does not accept responsibility for any injuries, damage to equipment, or costs incurred from projects, tutorials or suggestions in The MagPi magazine. Laws and regulations covering many of the topics in The MagPi magazine are different between countries, and are always subject to change. You are responsible for understanding the requirements in your jurisdiction and ensuring that you comply with them. Some manufacturers place limits on the use of their hardware which some projects or suggestions in The MagPi magazine may go beyond. It is your responsibility to understand the manufacturer's limits.



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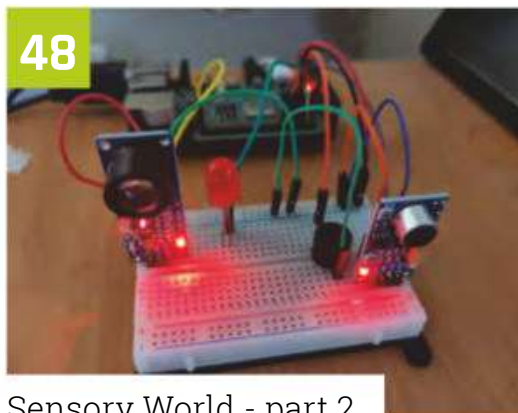
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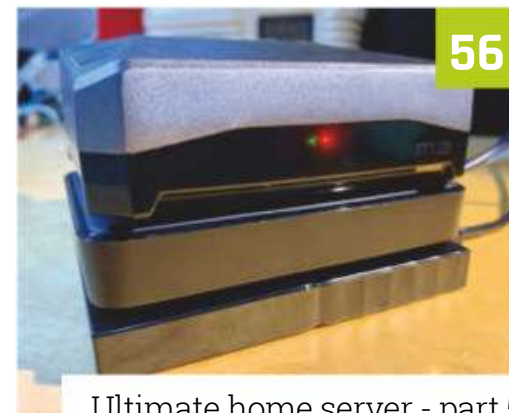
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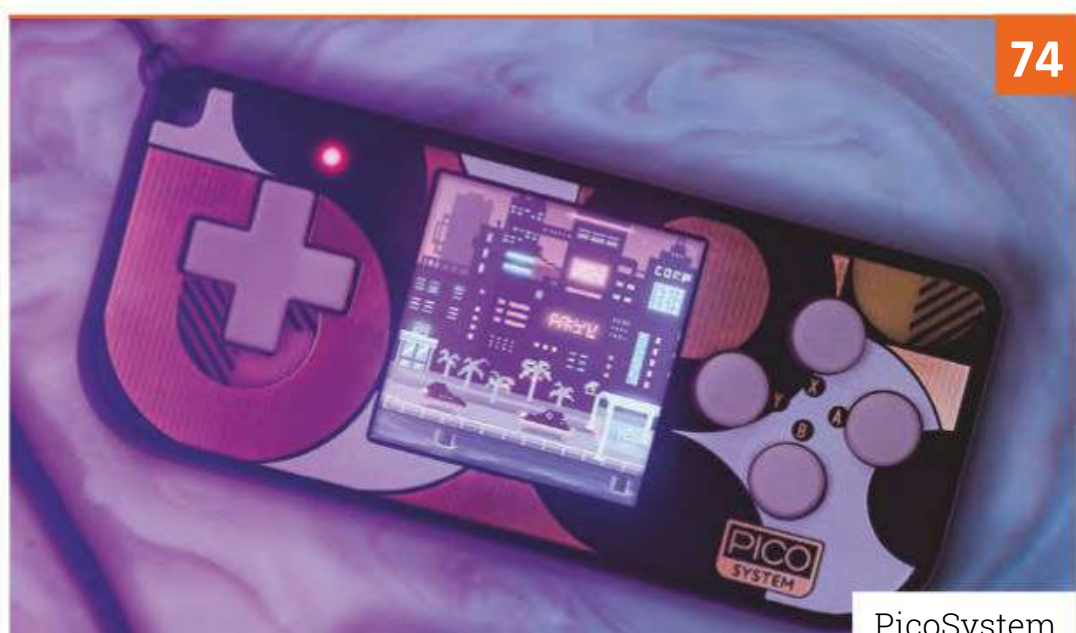
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# Robot Arm Clock

A deliberately over-engineered timepiece provided a satisfying distraction for a busy software engineer, learns **Rosie Hattersley**



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**Hendrik Ohrens**

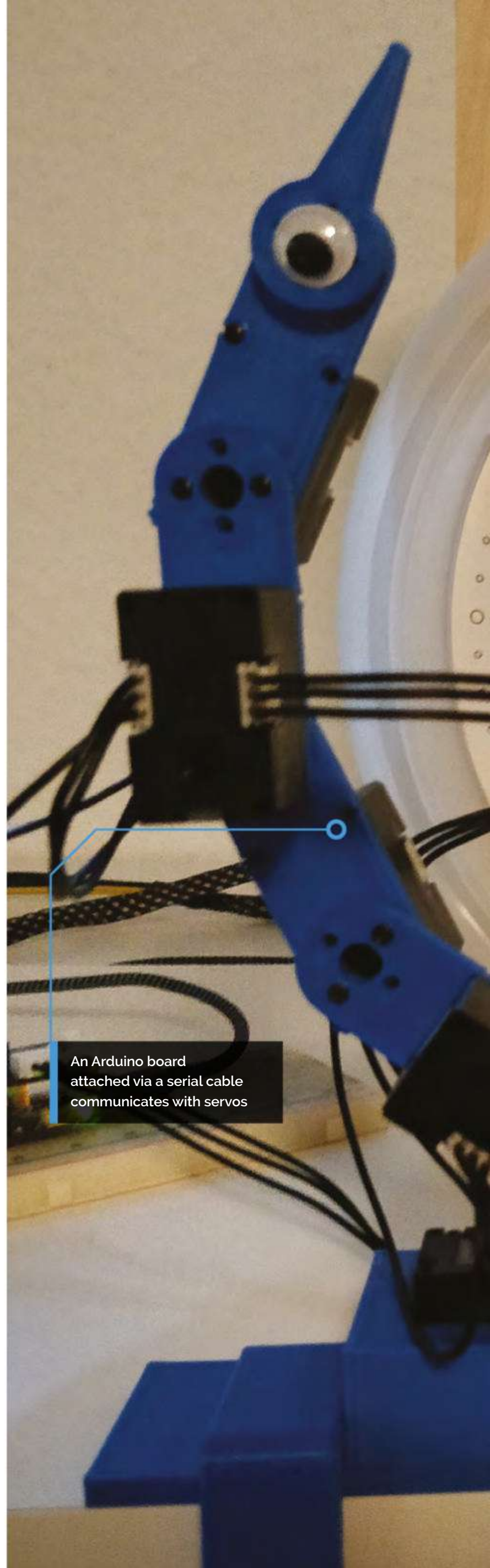
Full stack software developer Hendrik enjoys playing lacrosse, and making things in his spare time.

[magpi.cc/robotarminsta](https://magpi.cc/robotarminsta)

**L**ike many of us, 33-year-old software engineer **Hendrik Ohrens** likes to combine the technical skills he uses for work with those he's picked up through his hobbies, to come up with something creative. "I love working on projects that involve electronics, mechanics, and software," he says of his enthusiasm for making things. With a background in scientific research and mechanical engineering at the University of Hannover, plus a few Raspberry Pi builds under his belt, he decided it was time to challenge himself to design his first robot. He decided on a robot arm, since it seemed relatively simple to design but "still has some degree of flexibility". When Hendrik's existing clock stopped working, the idea of using a robot arm to move the dials to the correct position immediately sprang to mind. View the robot arm clock in action on Instagram: [magpi.cc/robotarminsta](https://magpi.cc/robotarminsta).

## Monitoring every movement

Hendrik began by using inverse kinematics to work out how to control his robot arm's motion – a scenario that involves using formulae to determine where the end of the arm will swing round to – but soon realised this wasn't the best approach. Instead, he switched to Raspberry Pi 3B+, with the intention of continuing to explore inverse kinematics and the `ikpy` library alongside AI and computer vision. In the end, he found training the robot to adopt specific poses was the most useful approach for his needs. "The position teaching feature allows me to move the arm to a position (with my hands) and then save that position for further use. This feature turned out to be very useful for the tasks the robotic arm performed after that," Hendrik explains.



An Arduino board attached via a serial cable communicates with servos



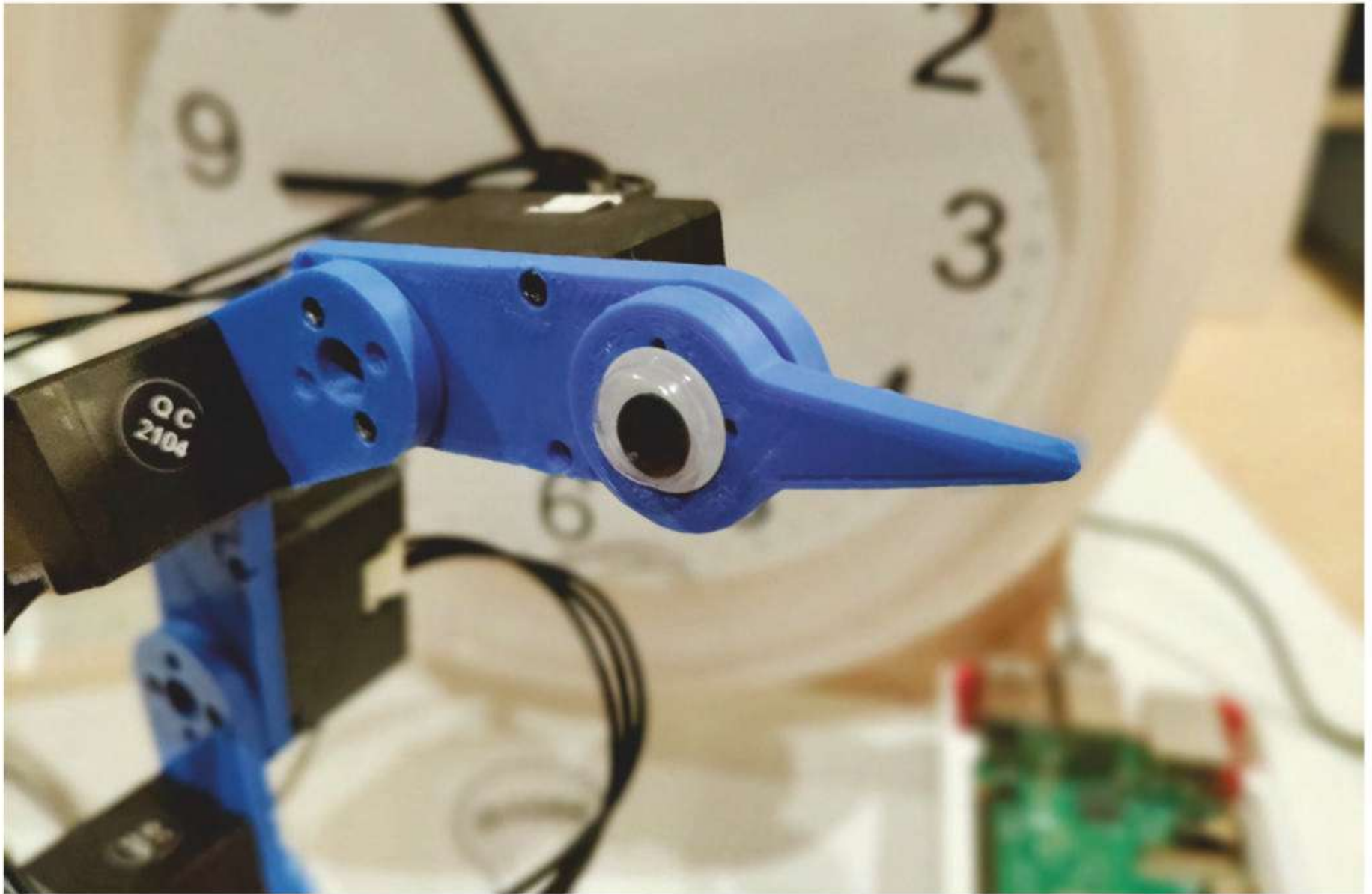
Quick **FACTS**

- ▶ Hendrik allows his projects to take shape organically
- ▶ He says the charm of making is to watch things happen when they happen
- ▶ But remember to double-check your 3D designs before printing them!
- ▶ Hendrik's previous project was also a robot arm
- ▶ He trained it to chase a rubber duck

When the clock stopped working, Hendrik decided to use the robot arm to move its hands to show the time

Raspberry Pi 3B+ provides the processing power needed to issue precise position instructions so the robot's arms mimic the hands on the clock





▲ Adding stick-on googly eyes was an instant way of giving the robot arm clock personality

► The robot arm moves the clock's minute hand to update the current time

“Hendrik has not only worked on other Raspberry Pi projects, but has accrued enough of them over the years to possess a dedicated Pi Box to keep them all in ”



“Raspberry Pi is the perfect development tool for me. It is powerful, versatile, and offers all I need to prototype my projects,” he says. Hendrik has not only worked on other Raspberry Pi projects, but has accrued enough of them over the years to possess a dedicated Pi Box to keep them all in. “The fact that I can run modern full stack applications, as well as talk directly to connected hardware, makes it my first choice when I prototype a project.”

He decided on an Arduino to talk to the servos using the manufacturer’s library, and Raspberry Pi to handle all the logic, as well as controlling the Arduino attached via a serial interface and a USB cable. For this he wrote custom code, refined over time (and still ongoing) to control the arm.


### Sketching it out

Hendrik prefers to sketch out plans and adapt them as needed, rather than starting with a rigid design. For his robot arm, he started with some servos and a basic CAD model that would be easy to 3D-print and add small parts to. Once he was





happy with the basic design, he simply duplicated it to make additional movable parts and chained the servos using a cable.

The robot's arm needed to be mounted to prevent it toppling over, so Hendrik 3D-printed clamps he'd found on Thingiverse, and clamped the arm to the table. He then glued the broken clock (whose dials the robot arm would move) to a wooden box, which he also then glued to the table so it wouldn't budge. After some adjustments to the arm's movement, which squeaked because it slightly overlapped in places, Hendrik began the far lengthier process of training the robot which position to adopt when. Having created the somewhat expanded motion-control code, he says the robot arm could be used for any sort of Raspberry Pi project he likes. 

▲ Teaching the robot arm which position to adopt involved demonstrating each pose

## Arm yourself



- 01** Download and 3D-print the robot arm parts, including a clamp for the table, if needed. Hendrik used five Dynamixel XL330-M288-T servos, along with an Arduino board and Raspberry Pi 3B+ for his version.



- 02** Attach and install a Dynamixel Shield and Arduino MKR, then flash `dynamixel_api` from the `code/arduino` folder to your Arduino. You also need to set up and install Python 3 and `ikpy` lib on your Raspberry Pi and attach a power supply.



- 03** Build the robot arm by putting a servo in the base; screw the `base_element` on to it, followed by the `arm_elements`. Clamp the base to a table or something solid, otherwise the arm will fall. For complete setup details and code, see: [github.com/devdrik/robo-arm](https://github.com/devdrik/robo-arm).



# Aston Martin DB5 Junior

To make an authentic James Bond-style Aston Martin, the only choice was a Raspberry Pi.

**Rob Zwetsloot** casts a GoldenEye over it



MAKER

**Simon Richardson**

A senior electrical engineer at The Little Car Company, who learnt Python on Raspberry Pi.

[thelittlecar.co](http://thelittlecar.co)

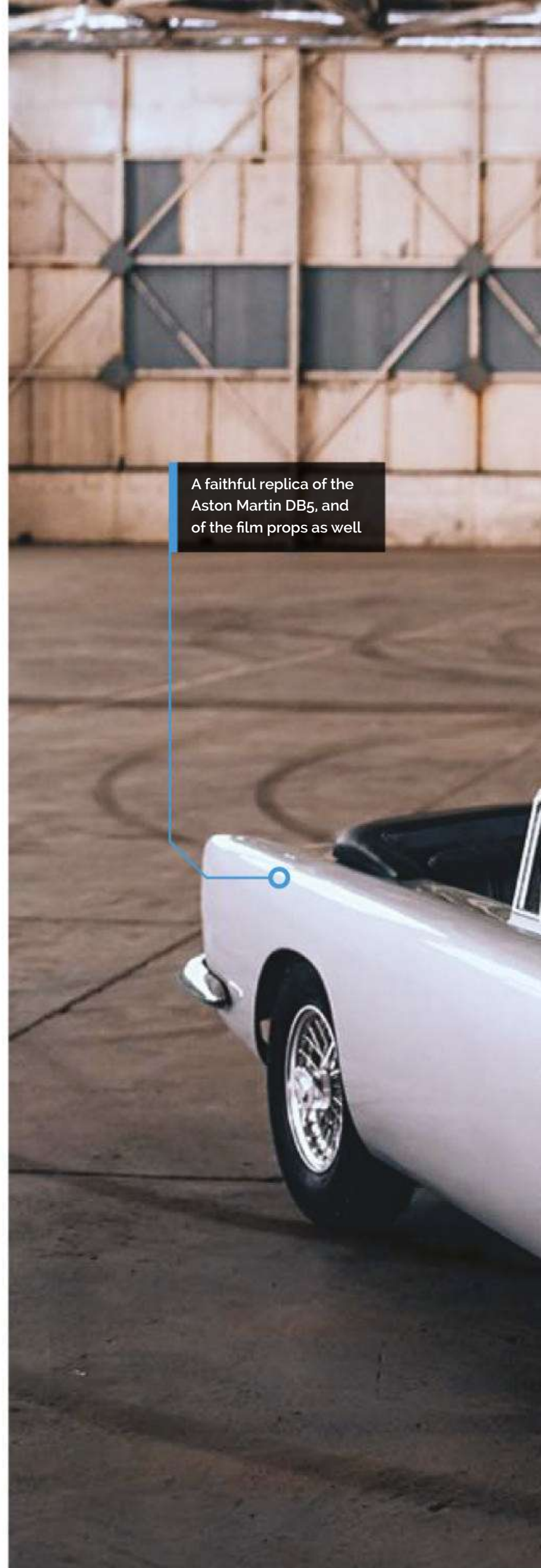
**O**ne of the most iconic cars in cinema history, the Aston Martin DB5 remains extremely cool to this day – even without the many enhancements that Q installed into James Bond’s vehicle. A real Aston Martin DB5 will set you back an unimaginable amount of money, and won’t even have changing number-plates as standard. If you’re happy with something a little smaller, cheaper, and a bit more eco-friendly, The Little Car Company has a solution for you: the Aston Martin DB5 Junior No Time To Die Edition – which uses some Raspberry Pi magic behind the scenes.

“As we needed to control two screens, Raspberry Pi 4 was a logical choice as it has dual HDMI outputs,” Simon Richardson, Senior Electrical Engineer at The Little Car Company, tells us.

A faithful replica of the Aston Martin DB5, and of the film props as well



▲ The smokescreen pours out of the (decorative) exhaust





Quick **FACTS**

- ▶ Raspberry Pi is used to test other cars at The Little Car Company
- ▶ The DB5 Junior is powered by four 1.8kWh batteries
- ▶ The extra driving modes are: Novice, Expert, Competition, Escape
- ▶ There's an hour's worth of smokescreen in the tank between top-ups
- ▶ A real DB5 will set you back about £1 million

The number-plate is a digital screen that Raspberry Pi can switch the numbers on

Hidden mini guns lurk behind the headlights, ready to be activated





◀ If it weren't so small, we'd swear it was the real thing

▼ The hidden control switches are accurate to the films



Those two screens? The changeable, digital front and rear number-plates of the DB5 Junior. Luckily, it's not a real car, so you get authentic licence plate numbers from the films. Raspberry Pi also controls hidden mini guns behind the headlamps.

“ Raspberry Pi also controls hidden mini guns behind the headlamps ”

▼ Testing the number-plate screens in daylight to make sure they work properly



### Small but mighty

Even though it's not a proper road car, it is still quite a lot of car. With a 21.5bhp electric motor, it can reach top speeds of over 45mph, and has an array of driving modes for more advanced control. There's even a skid mode for if you want to do some cool doughnuts or other theatrical evasive manoeuvres.

As for extra gadgets, there's a working smokescreen that can be ejected from the exhaust, and it's all controlled by a hidden control panel.

“When the guns are activated, Raspberry Pi activates relays that control the linear actuators and monitors the limit switches so that the power is cut when the actuator reaches the end of its stroke,” Simon explains. “Raspberry Pi controls the sequence of movement so that the guns cannot move unless it is confirmed that the lights have been lowered. The lights will not raise unless the





Alternative number-plate 1



Alternative number-plate 2

guns are confirmed as having retracted. Raspberry Pi also plays the machine gun recording when the guns are ‘fired’, and an LED in the gun lights up.”

### Licence to thrill

It’s a fairly simple setup, requiring a Raspberry Pi 4, an I/O extender, and some timer chips – although Raspberry Pi can handle much more than it’s used for.

“As a demonstration of the system’s capabilities, I coded it to show the movie trailer on the front screen when the licence plate button was pressed and held,” Simon mentions. “This included playing the audio too. It also played the audio of a theme tune when another button was pressed and held.”

The car has appeared on TV in the UK and in the USA, and according to Simon, it’s the most interest they’ve ever had for a product.

You can also get a regular version of the DB5 Junior if you don’t fancy the extra gadgets, but where’s the fun in that? [M](#)

## All systems go



- 01** When the car’s ignition is switched on, a 555 timer creates a pulse that triggers a Witty Pi board to switch Raspberry Pi on. The program runs automatically, with the cursor and splash screen disabled so that the screens remain blank until the default licence plate image is displayed.



- 02** The licence plate images are the same as those used on the car in the film. The images are referenced in an array – when the switch is pressed, the screen changes to the next image in the array. When it gets to the last image, it goes back to the first image again when the switch is pressed.



- 03** When the gun is activated, the headlights are retracted, and when that is confirmed, the relays will activate to present the guns, stopping at the maximum swing. The same happens in reverse, with the guns confirmed stored before the lights return.



# Droiid – A Package Delivery Robot

Here's an autonomous, efficient bot who'll deliver goodies to your doorstep. **Nicola King** waits for her order...



**Eben Kouao**

Eben builds DIY prototypes based on new technologies. From smart mirrors to delivery robots, you can find more of his projects at [smartbuilds.io](http://smartbuilds.io).

[magpi.cc/ebenkouao](http://magpi.cc/ebenkouao)

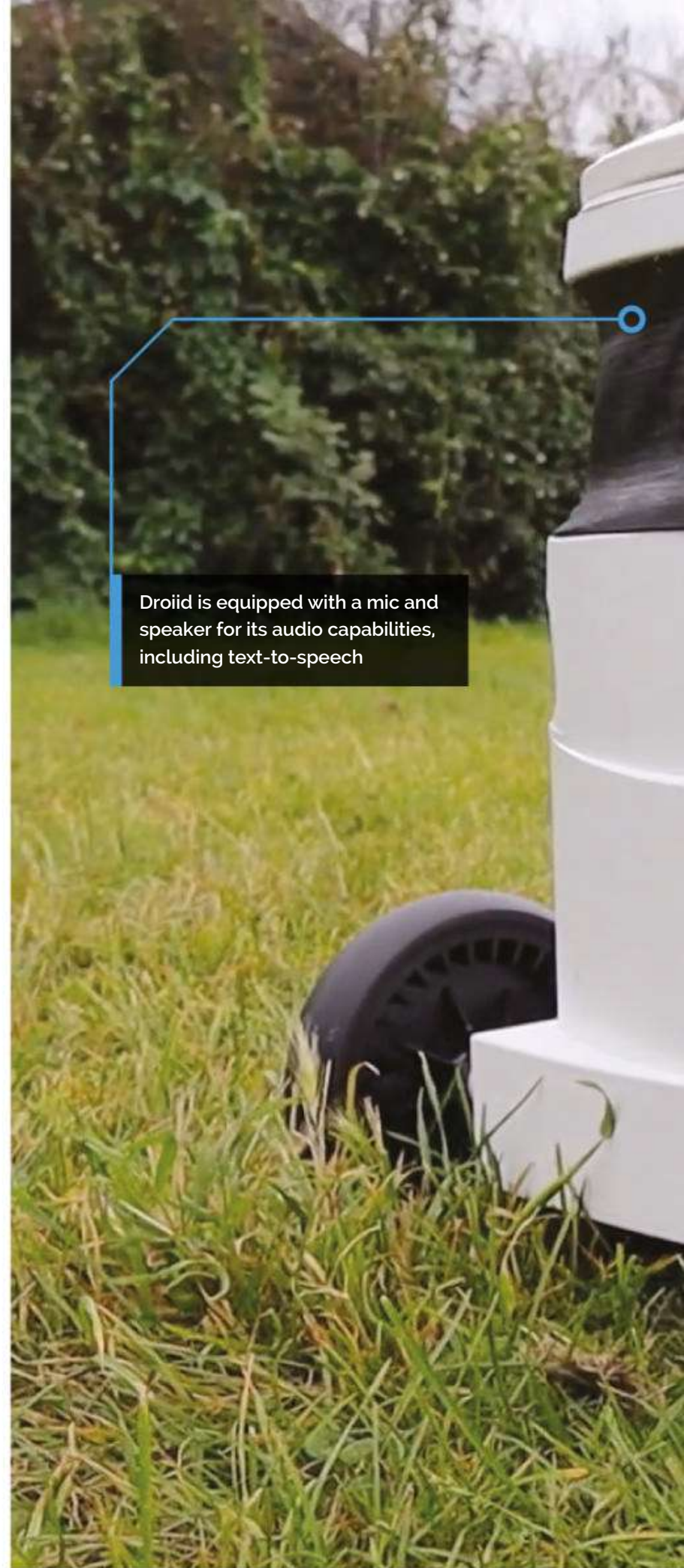
Inspired by the likes of Amazon and Starship, two companies that have both created six-wheeled delivery robots ([magpi.cc/amazonscout](http://magpi.cc/amazonscout) and [starship.xyz](http://starship.xyz)), UK-based Eben Kouao wondered if he could possibly build a similar vehicle. As powerful mini-computers become more accessible, Eben started building his own version with a Raspberry Pi and an Arduino, and the result of his labours is Droiid, a clever robot that can be controlled from anywhere in the world.

## Direct Droiid

“Droiid came through the inspiration of recent innovations going on within the delivery market,” Eben tells us. “As online consumer demand increases, to keep up with growing demand, the idea of autonomous drones delivering small packages to your doorstep isn’t too far off reality.”

Furthermore, a Raspberry Pi 4 is central to how this robot operates, as Eben explains: “The robot can be seen as a Raspberry Pi connected to an Arduino attached to motors. Raspberry Pi acts as the orchestrator behind controlling all components of the robot.”

In terms of dimensions, Droiid is not huge (330 mm W × 380 mm H × 340 mm L), but it has a compartment big enough to hold small parcels or food deliveries, and it can be controlled remotely via a livestream chat from anywhere in the world.

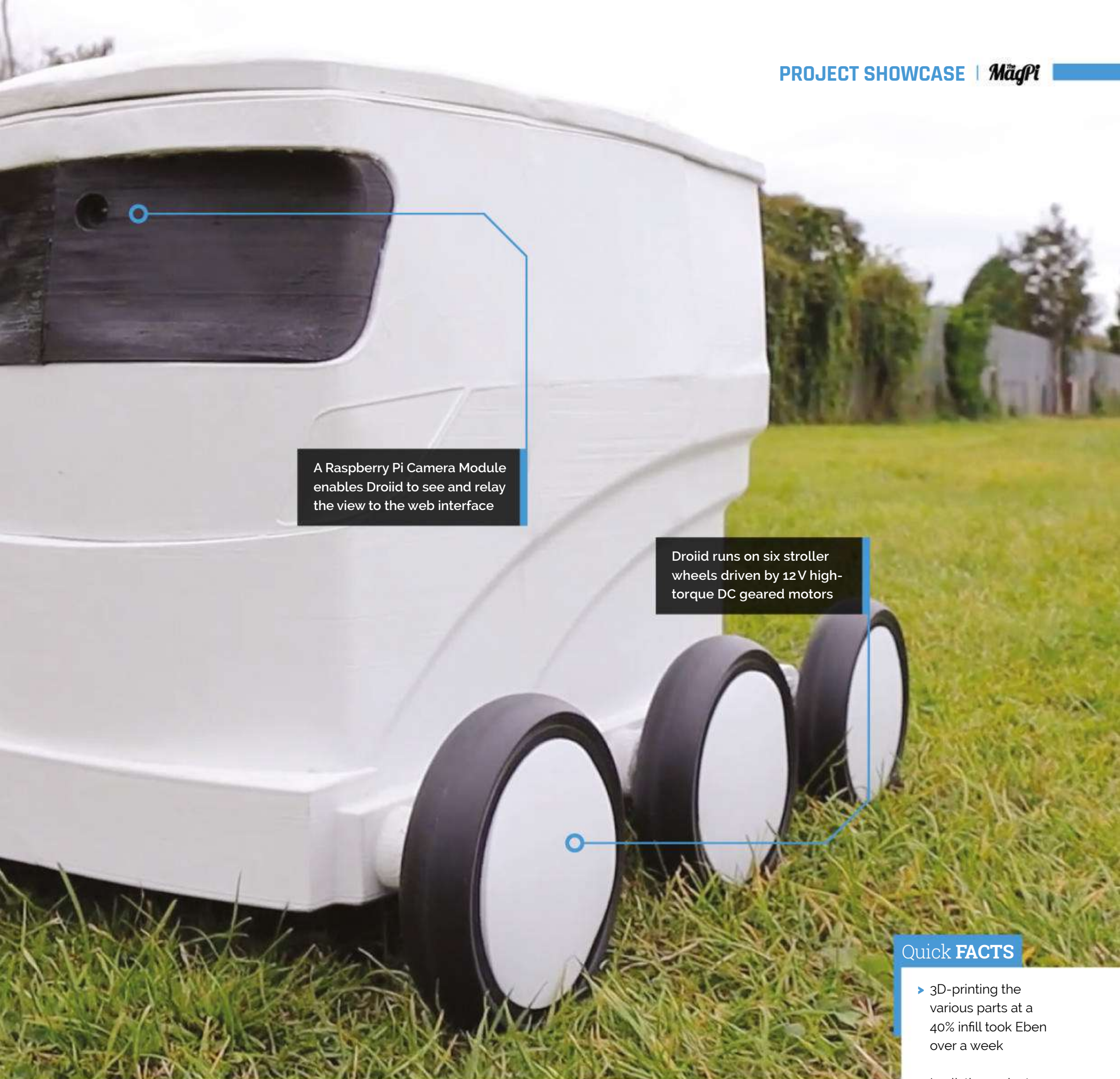


Droiid is equipped with a mic and speaker for its audio capabilities, including text-to-speech

Eben has also attached a Raspberry Pi Camera Module, a speaker, and a mic module, and so the robot’s view of the world can be streamed on YouTube or Twitch. Droiid can be controlled through the livestream chat. For instance, a user can write a command (as a message) in the live chat to Droiid, e.g. ‘move? Right’. This command is then sent to a server, and Raspberry Pi receives that message from the server. Raspberry Pi then sends the command to the Arduino, and Droiid receives the message and executes the function.

In addition, as well as giving the robot a command to move, users can use TTS (text-to-speech). So,





A Raspberry Pi Camera Module enables Droiid to see and relay the view to the web interface

Droiid runs on six stroller wheels driven by 12V high-torque DC geared motors

#### Quick **FACTS**

- ▶ 3D-printing the various parts at a 40% infill took Eben over a week
- ▶ In all, the project took several months to create
- ▶ Eben is no stranger to project-building with Raspberry Pi
- ▶ Take a look at his Smart CCTV Camera: [magpi.cc/eksmartcctv](http://magpi.cc/eksmartcctv)
- ▶ ...Or his Smart Mirror AI: [magpi.cc/eksmartmirror](http://magpi.cc/eksmartmirror)

using the ‘say?’ command at the start, users could tell Droiid to say ‘Hello, today is Thursday.’

### The wheel deal

Droiid was built using 3D-printed parts and, due to the size of the project, the printing had to be broken down into smaller parts in order to be accommodated on the 3D printer bed.

Eben decided to equip Droiid with six wheels mainly as a trade-off between the robot’s cost and its power. “An earlier model of Droiid used four wheels,” he shares. “However, using six wheels seemed to be the sweet spot to get as much power

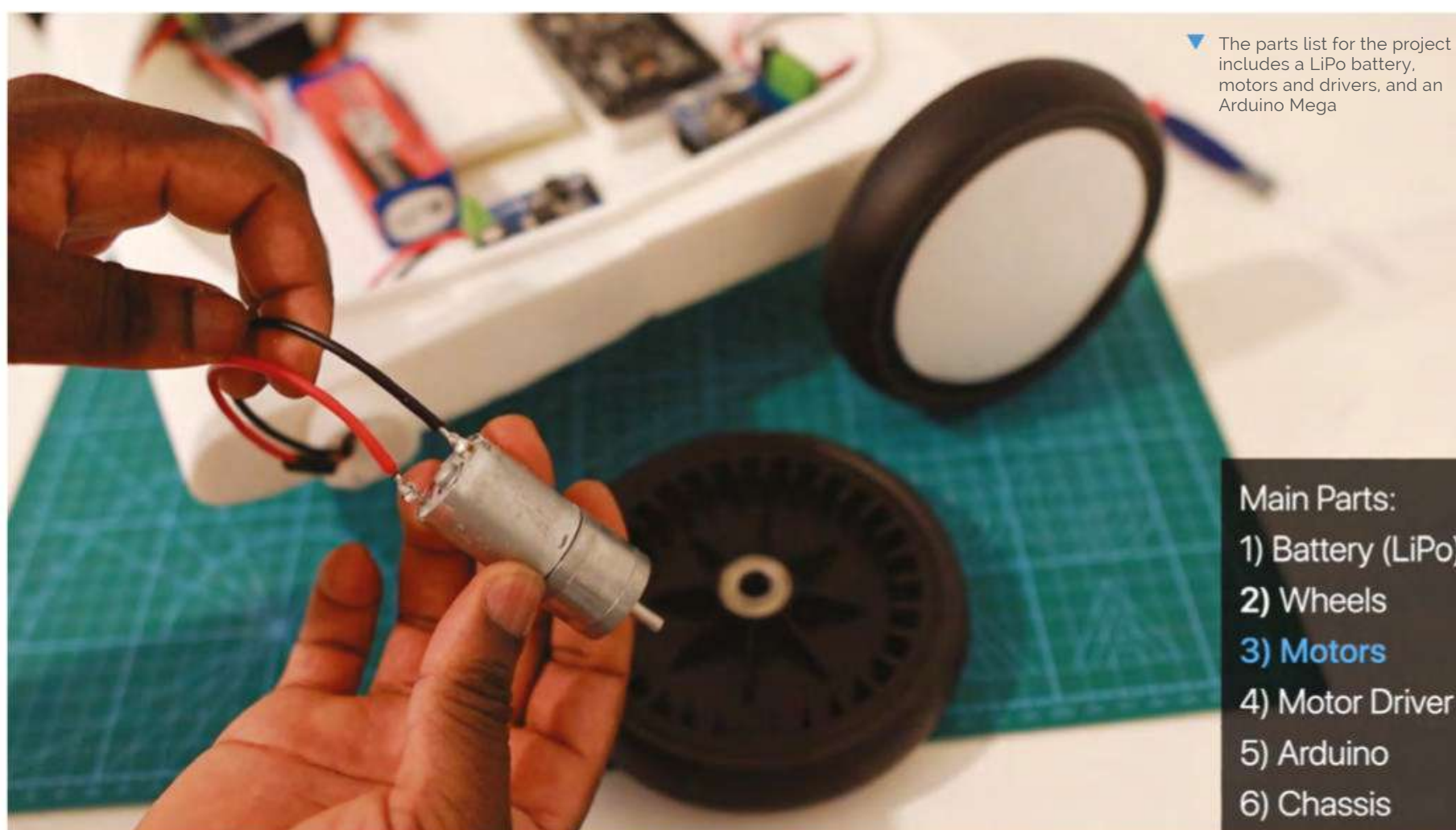
[as possible] from the 12V geared DC motor to climb inclines with a payload.”

To aid stability over rougher terrain, such as grass, an accelerometer was added so the tilt level can be monitored. An ultrasonic sensor gives Droiid spatial awareness and the ability to detect obstacles. Finally, a bottom-mounted WS812B LED strip lights the way for the robot in the dark.

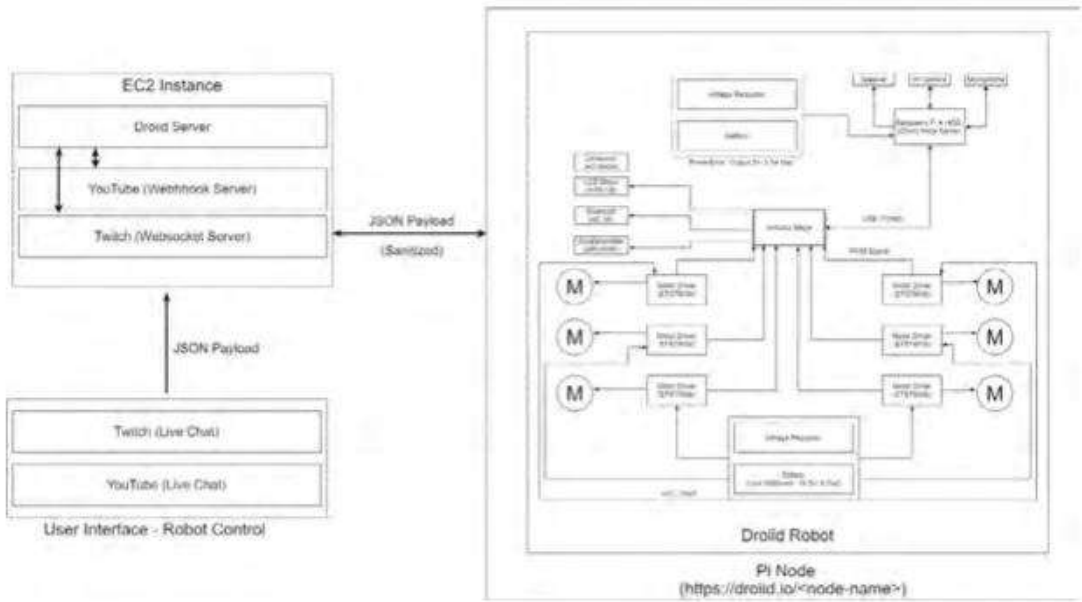
### Exciting possibilities

The feedback that Eben has received from all corners has been hugely positive, as there are clearly exciting possibilities regarding how










such a robot can be used. “It’s definitely a conversation starter,” he remarks. “From the maker community, it’s also been awesome – some others are curious how it works and what’s next. I’m now working to take it out to deliver an actual package!”

▲ A high-level block diagram showing how all the elements of the project work together

“ I’m now working to take it out to deliver an actual package! ”

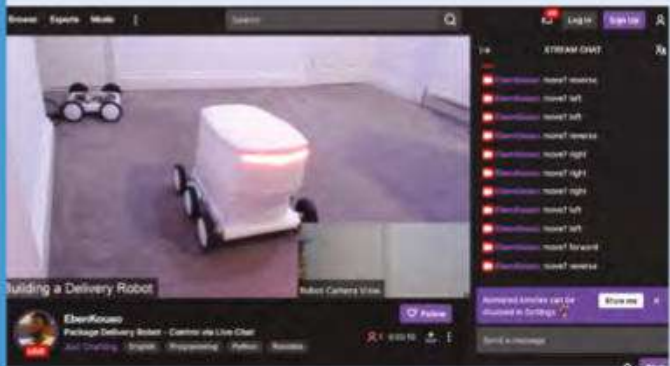
This is just version 1 of Droid and Eben guarantees that a lot more “features and intelligence” are on the way. Emboldened by the success of the build so far, he is intent on making a number of upgrades. These include improving Droid’s latency using Apache Kafka – an event streaming platform – so that the time taken from a message being sent to Droid, to the robot actually performing the action requested, is improved. Eben has also created a couple of additional robot models, including Droid Mini, which is the four-wheeled version, and is keen to explore the concept of widening the cohort of people who can actually control Droid’s movements. “The idea of others controlling the robot over livestream to complete tasks [or at] sports events is something I’m interested in looking further into,” Eben enthuses. 

## Controlling Droid

Using the livestream chat in YouTube or Twitch, Droid can be instructed to move or say something.



**01** A user writes a robot command as a message in the livestream chat. This is received by the Droid Server, parsed as a JSON object, and sent to Raspberry Pi.



**02** If it’s a ‘say’ command, Raspberry Pi sends it to a speaker; if it’s a ‘move’ command, it relays it to the Arduino that controls the robot’s motors.



**03** Alternatively, Droid can be controlled manually using the **W**, **A**, **S**, and **D** keys via a remote web interface that includes the view from its on-board camera.



# Honeycomb Wall Shelf

**David Crookes** discovers how Raspberry Pi can shine a whole new light on even the most everyday of household items

▲ The shelf displaying a Doctor Who and TARDIS model



MAKER

## Jason and Jessie Logan

Jason and Jessie seek new experiences with wanton abandon in New Hampshire, and the universe at large.

**H**aving recently married, Jason and Jessie Logan decided it was time to put their stamp on their first home. “We wanted something that would really be unique,” Jason says. “And some shelves for the living room to display our adventures and interests seemed like the right concept.”

Rather than opt for basic horizontal shelving, however, the newlywed couple settled on a hexagonal design. “Jessie set about with construction paper making templates and rearranging them on the wall until we were satisfied,” Jason continues. “I then wanted them to light up.”

It was this decision that took the project to the next level, creating an eye-catching set of shining shelves. Although the couple says 3D printing was perhaps a bit ambitious, outputting the six pieces for each individual shelf on their Creality Ender 5 Pro 3D printer put the couple in control. “Printing them allowed for all of the elements we needed, while not overburdening the drywall.”

### Pieces of six

Each of the six pieces incorporates a channel that allows the lights to shine and the idea was to glue each part together to form the hexagonal shapes. “We also created standoffs, some of which were hollow to allow for chasing wires into the wall, and others that could be used with toggle anchors or wood screws in case of a pesky stud,” Jason says.

Since the couple wanted the lights to dim and change colour, they decided to use a Raspberry Pi 4 computer to control the whole set of shelves. “You can program, debug, search the internet for

solutions and libraries, and make use of the GPIOs without leaving the lab,” he explains of the benefit of using this particular model early in the build. “Then, when it’s all ironed out, you can drop the program on to a Raspberry Pi Zero or Raspberry Pi Pico to gain efficiency and save some coin.”

To get things up and running with a set of 12V RGB light strips, they used pulse-width modulation, which is a common way of controlling the dimming of RGB LEDs. It meant the project could adjust how much red, green, or blue is being displayed.

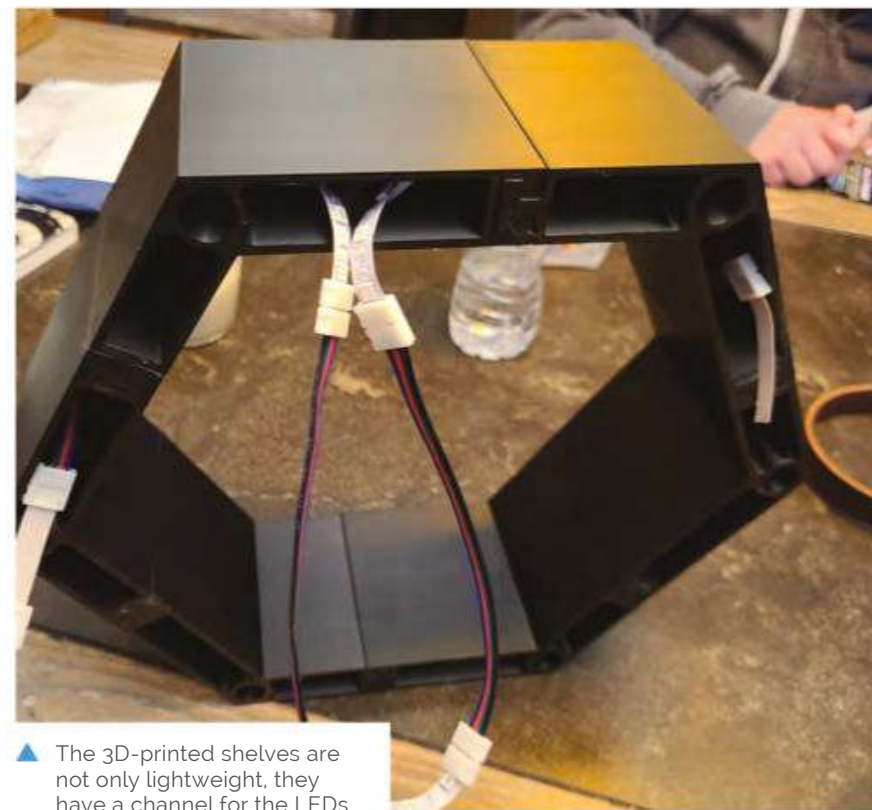
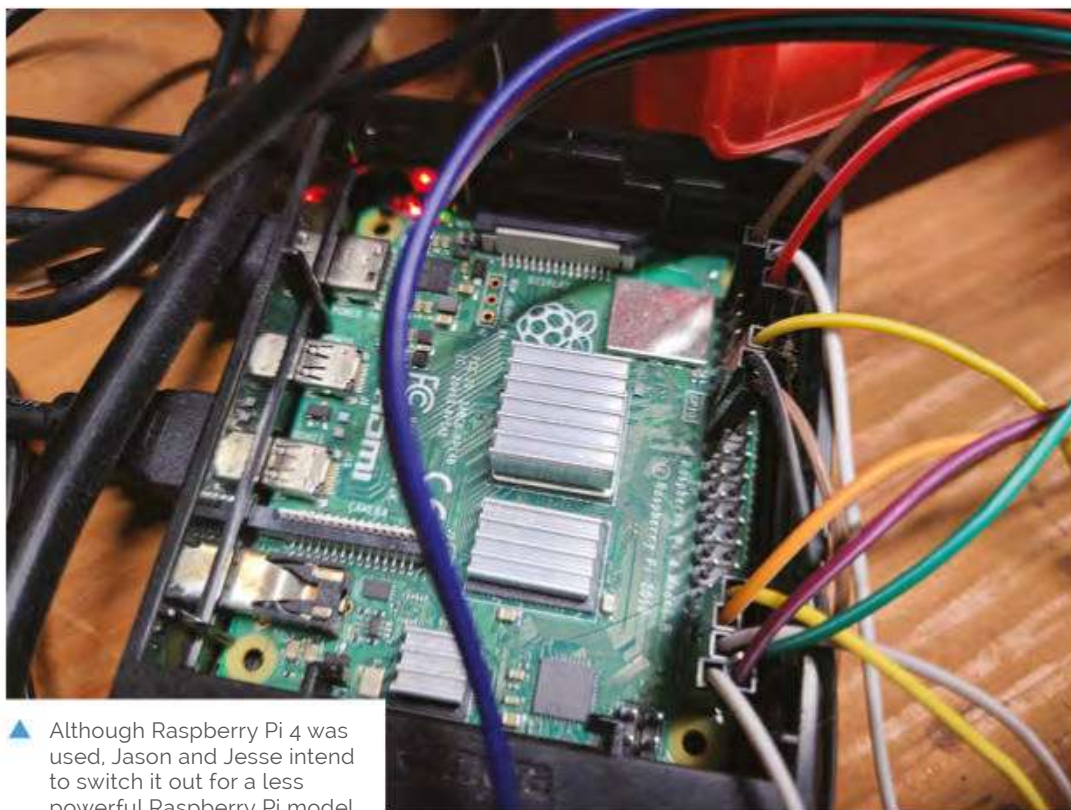
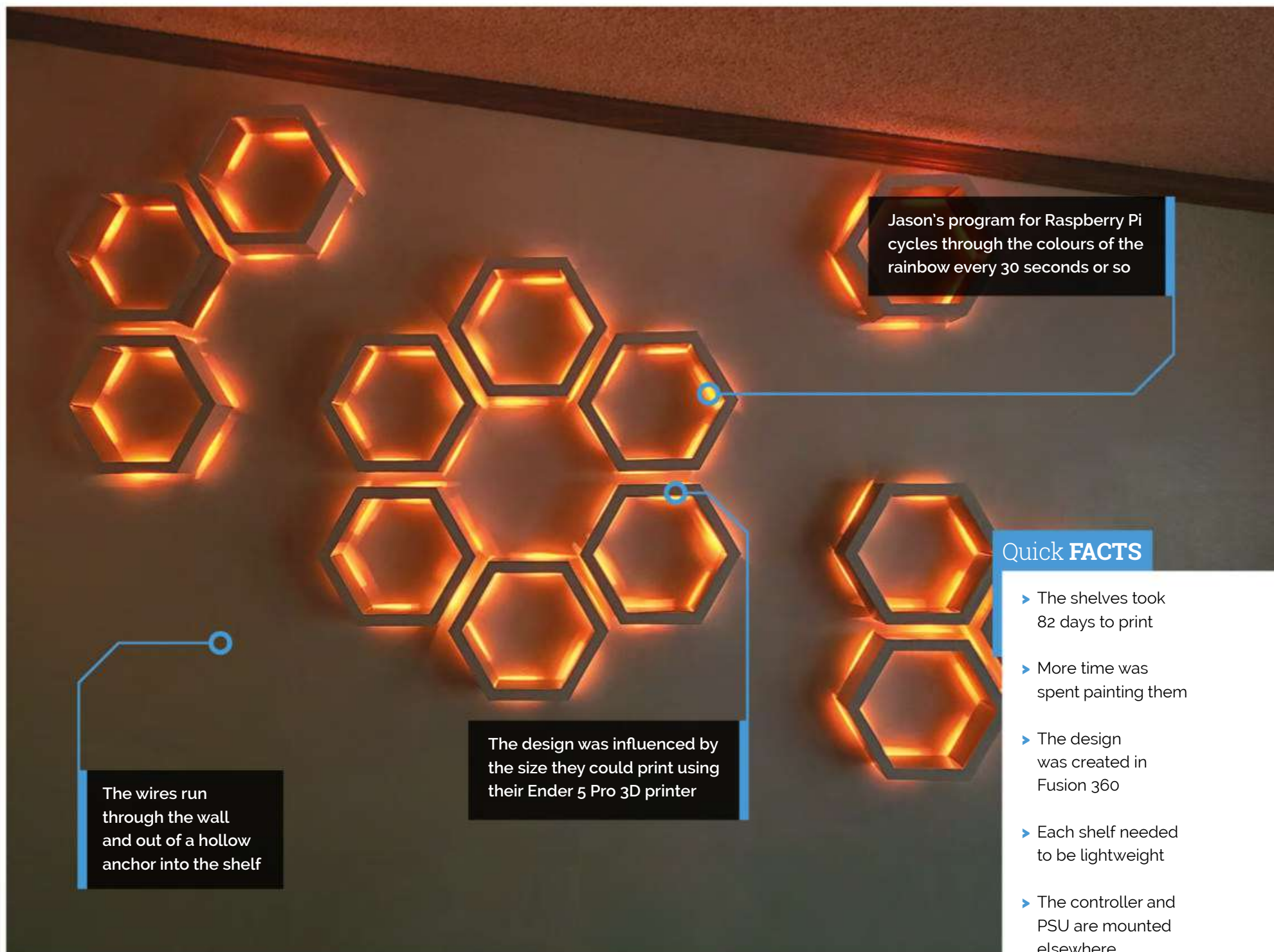
“We plan to use touchpads printed in Gallifreyan”

### Time to improve

“Since Raspberry Pi can only control a 3.3V circuit in this manner, we used three NPN transistors and three IRFZ44N MOSFETs to step it up to 5V, and then to the 12V that the light strip uses,” says Jason, who adds that learning to size the MOSFETs properly for the job was the biggest challenge. “It taught us a lot about gating and output curves.”

The result was worth the perseverance, however, and now the couple want to go even further while adding an extra-special, personal twist. They are both fans of *Doctor Who* and they want to tap into the Gallifreyan language used by the Time Lords. “We plan to use touchpads printed in Gallifreyan coated in conductive ink as controls on the wall,” Jason reveals. “We just need to iron out some sensitivity issues.”







# Pomelo

A robot dog aimed at education for younger kids learning code.

**Rob Zwetsloot** finds out just how good a doggo it is



## Yoel Nasi

A high school student whose team share their passion for programming and making in their community.

[magpi.cc/pomelogit](http://magpi.cc/pomelogit)

**R**obot pets have been around for a long time. Raspberry Pi-powered ones, not so much though. While there are currently no Aibo-a-likes walking around people's houses, that is probably not too far off. Pomelo is a look at what might be, albeit with an educational leaning.

"Pomelo is a dog-shaped educational toy robot that is suitable for primary school classrooms, with the goal of promoting strong algorithmic skills in younger students," Yoel Nasi – part of the student team that made Pomelo – tells us. "Pomelo can be programmed to move in desired patterns and directions through physical code blocks. The blocks are similar to the regular 'ABC' blocks that children play with in elementary schools and contain commands such as move forward, turn left, and turn right. Teachers can create and assign puzzles or mazes to the students using the aforementioned code blocks."

Usually when we talk about code blocks in *The MagPi*, we're referring to Scratch or other languages that use blocks of code. Pomelo uses literal, physical toy blocks for its programming. These blocks have a little description of what

▼ Kids apparently love playing with Pomelo



▲ Pomelo has been displayed at many conferences, with a lot of interest shown

they'll tell Pomelo to do, and they're processed using a camera and QR-like codes on the blocks.

## Robot peace

"We've been making projects for quite some time, reaching the point where we are able to organize events such as our annual Hisar Coding Summit," Yoel explains. "[Here] students organize their own workshops to teach skills such as programming, electronics, CAD, etc... We were amazed by the environment and community after attending the Pi Wars competition in Cambridge for the past several years. Thus, to bring this culture and community to Turkey and encourage more students to pursue STEAM, we contacted the organizers of Pi Wars, who gladly accepted our proposal and supported us throughout our journey [to create Pi Wars Turkey]. Now in its third year, we have reached more than 400 students all over Turkey."

Pi Wars was not the students' first foray into Raspberry Pi either.

"We used the Raspberry Pi in many projects including Pomelo, as it was a tool that opened up many opportunities in electronics and portable computing," Yoel tells us. "We learned about the Raspberry Pi initially through our teachers. They showed us the multitude of projects that can be done with them, so we started to draw inspiration from multiple sources such as *The MagPi*, and made multiple projects including Pomelo."





### Quick FACTS

- ▶ The head can move up and down
- ▶ Pomelo is Spanish for grapefruit
- ▶ It teaches the logic of code
- ▶ Sony's Aibo has been around for 22 years...
- ▶ ... and the fourth gen came out in 2018

“Children were comfortable around Pomelo and enjoyed the toy-like aspects”

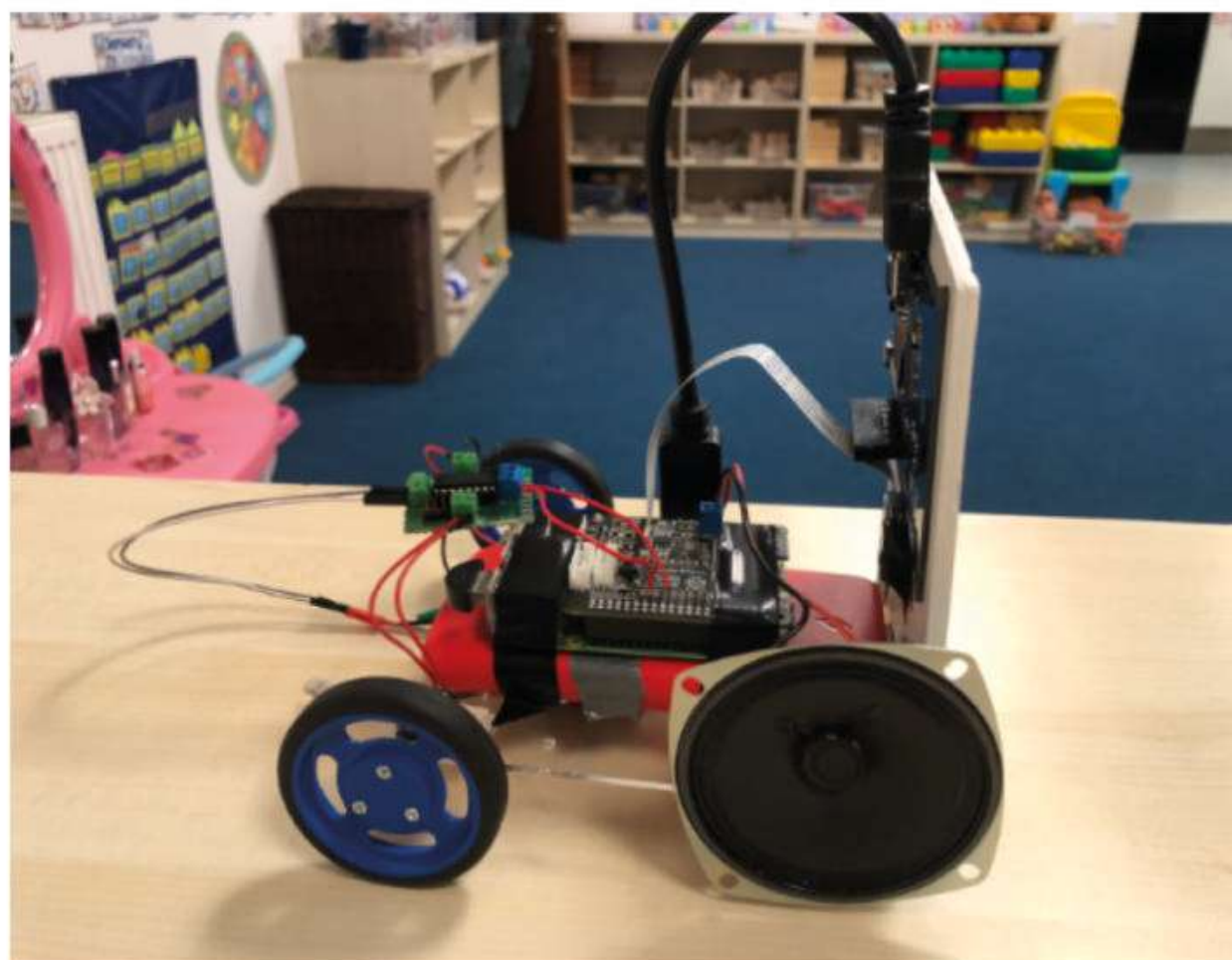
### Not just for Christmas

The team have been able to test out Pomelo in the real world, and so far it's gone well.

“Pomelo has mostly received positive reactions from all the conferences that we've been to,” Yoel says. “Observing their interaction with Pomelo, we were able to tell that children were comfortable around Pomelo and enjoyed the toy-like aspects to it, like the emotions it displayed with its eyes and the general design of it. They were also intrigued by the ability to command through the code blocks and tried to move it in different ways for the routes they came up with. They collaborated with each other to solve challenges like mazes by using Pomelo.”

Pomelo is currently an open-source project, so you can actually build one yourself right now! Head to the GitHub repository to find out more:

[magpi.cc/pomelogit](https://magpi.cc/pomelogit)



▲ The electronics for Pomelo are fairly simple



# Automatic Dog Ball Launcher

Are your games of fetch with your pooch leaving you panting?

**David Crookes** catches up with a Raspberry Pi Pico solution



MAKER

## Brankly

Brankly is an inventor and entrepreneur. He grew up in Germany and worked as an IT consultant for years before following his passion for inventing full-time.

[magpi.cc/dogball](https://magpi.cc/dogball)

**D**ogs love to play fetch and it's a wonderful way to exercise your pooch. Trouble is, constant ball throwing isn't half exhausting for human arms, which is perhaps why there's a growing number of automatic ball launchers on the market.

Rather than buy one of those, however, seasoned maker Brankly has created one of his own. "My dog loves to play with blue toy balls and I wanted him to have a little more fun," he tells us. "I also want him to be able to play fetch when we are busy by encouraging him to load the balls himself."

While training his dog to do so is still ongoing, work on the ball launcher is complete. It makes use of a Raspberry Pi Pico microcontroller board which is something of a departure for Brankly who has previously used Arduinos for his projects. "I

just wanted to try something new," he says. "I love how simple it is to program."

## Print perfect

Before getting down to coding, however, he spent time experimenting. "I started with the motor mount to test if that would launch the balls," he explains. "After that, I designed the other parts and, in the end, the case. I played around with different shapes and found that a sphere design looked the best. It was also small enough for my 3D printer to print."

The case was designed in Fusion 360. "I like 3D printing because you can design everything first, send it to the printer, and have the part after some hours," Brankly says. "Most of the time, you have to change small parts, but it's a pretty straightforward process." Indeed, he refined the project as he went along, such as the rollers that accelerate the ball.

"The first version had a profile printed on them, but the friction was not enough to grab the ball when it was wet from my dog's saliva," Brankly says. "I also had to change the mount for the sensor a couple of times because the first two sensors I tried didn't work."

## And fetch

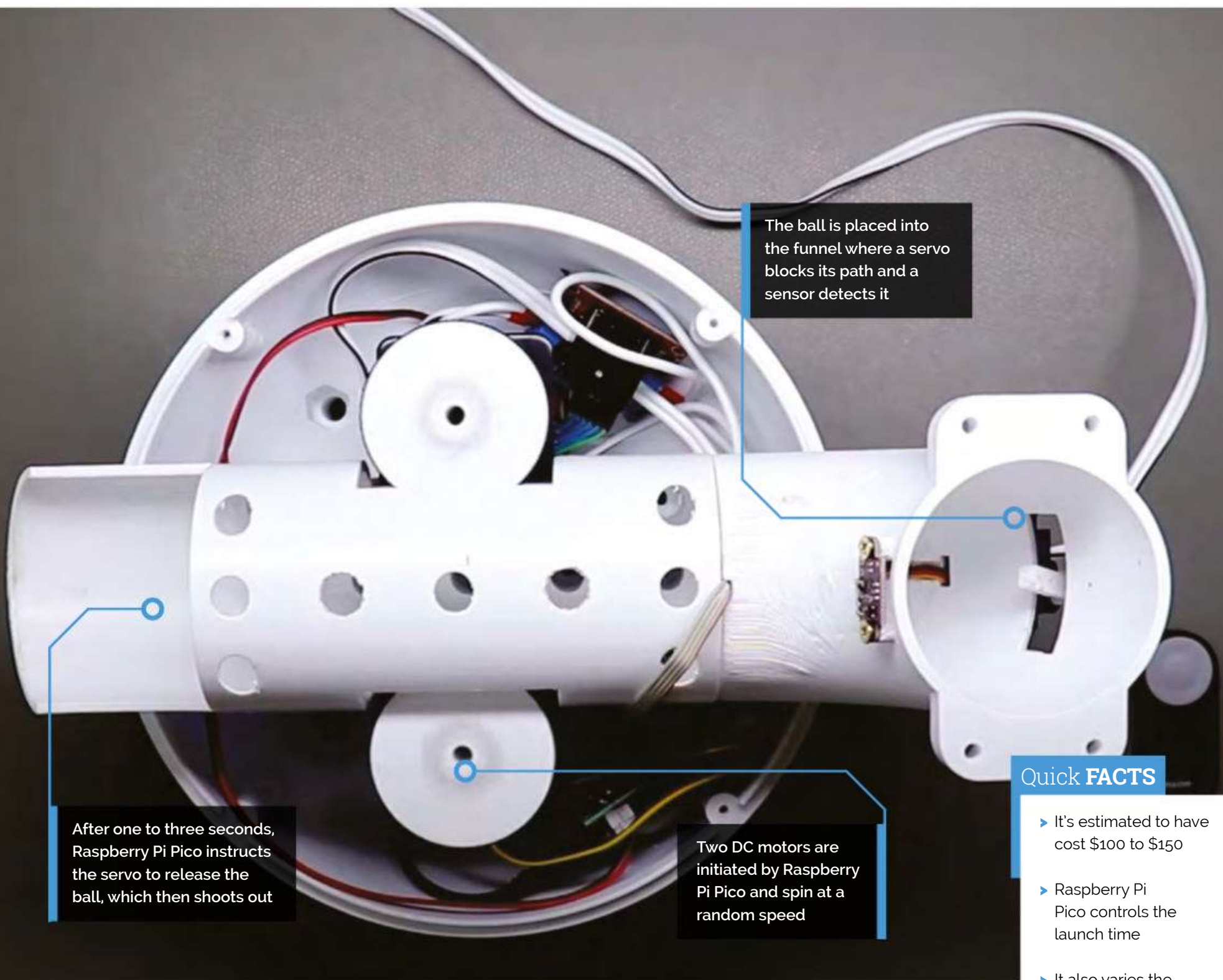
So how does the launcher work? When a ball is placed into its funnel, it is prevented from falling into the launch channel by a piece of plastic that's controlled using an SG90 servo. The ball is then detected by a sensor, prompting Raspberry Pi Pico to get ready for launch.

"I used a motor controller to be able to randomise the speed of the motors with a pulse-width modulation (PWM) signal," explains Brankly. "For each cycle, Raspberry Pi Pico generates a random number between 40,000 and 65,000, and this gets sent to the controller as a PWM value."



Brankly says the limitations of his 3D printer meant the components had to be cramped into the case more than he'd have liked





## Quick FACTS

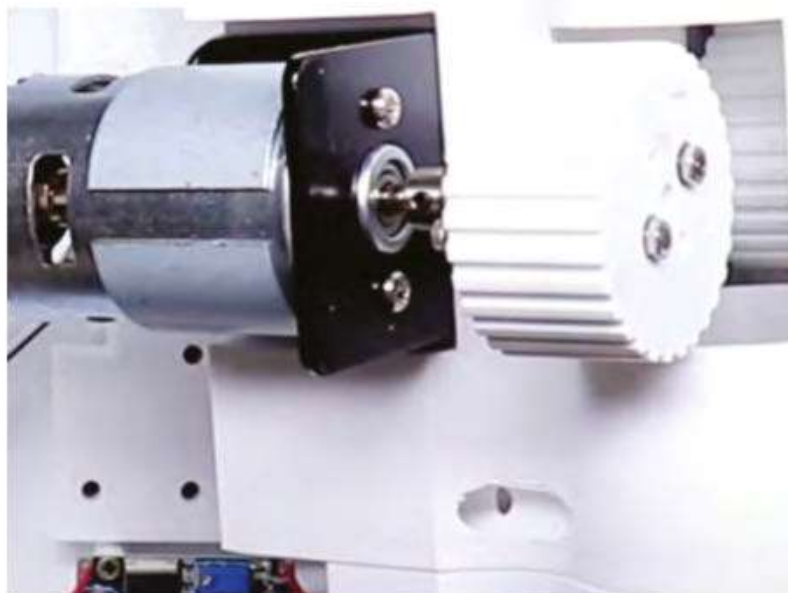
- ▶ It's estimated to have cost \$100 to \$150
- ▶ Raspberry Pi Pico controls the launch time
- ▶ It also varies the motor speed
- ▶ Make sure to use soft balls
- ▶ Print files are on Thingiverse: [magpi.cc/dogballthingiverse](https://magpi.cc/dogballthingiverse)

“I used a motor controller to be able to randomise the speed”

“This will vary the distance of the ball each time so it's more fun for my dog. After the motors are started, the ball releases and gets shot out. The motors turn off, the servo blocks the entrance again and the machine is ready for the next ball.”

The approach adds an element of uncertainty and means a dog won't know exactly when the ball is going to launch, or how far it's going to travel. “I'm really happy with the end result,” Brankly says. “I think the design looks pretty cute and my dog really loves it. He gets all excited when he hears the machine starting up.”

▼ The motor controller can be seen to the left, with the motors themselves in the centre of the image







▲ By determining the servo angle, it's possible to control the amount of food that ends up in the tank

# Finn Feeder

One maker and his son are making sure the fish they buy will never go hungry with a project that's going swimmingly well, as **David Crookes** discovers



Ryan M Haas

MAKER

Ryan is an electronics and software hobbyist from Pennsylvania, USA. He enjoys time with his family, as well as home improvement projects.

[magpi.cc/autofishfeeder](http://magpi.cc/autofishfeeder)

**W**hen Ryan M Haas's son asked if he could have a fish tank, it quickly became clear there would be a problem.

"We're away from home a lot, so I knew there was a possibility the fish would go long periods without being fed," Ryan says. Yet he didn't want to deny his son's request.

Instead, he came up with a "fin-tastic" solution. "I had seen automatic pet feeders in the pet stores, but I knew I would be happier with my own design," he tells us. "My son is also enjoying his technology education classes in high school. I thought this project would be something fun for us to work on together."

With that in mind, the pair got to work, with Ryan spending twelve hours planning the project's Python code, and working out the database structure he needed to track the feeds. He used a single SG90 servo and 3D-printed parts, putting Raspberry Pi Zero W at its heart.

## Nothing fishy

"This project represents my first design of my own and there was a learning curve on how to design parts for the best printing quality, ease of

assembly, and part-alignment for the fitting of the screws," Ryan says.

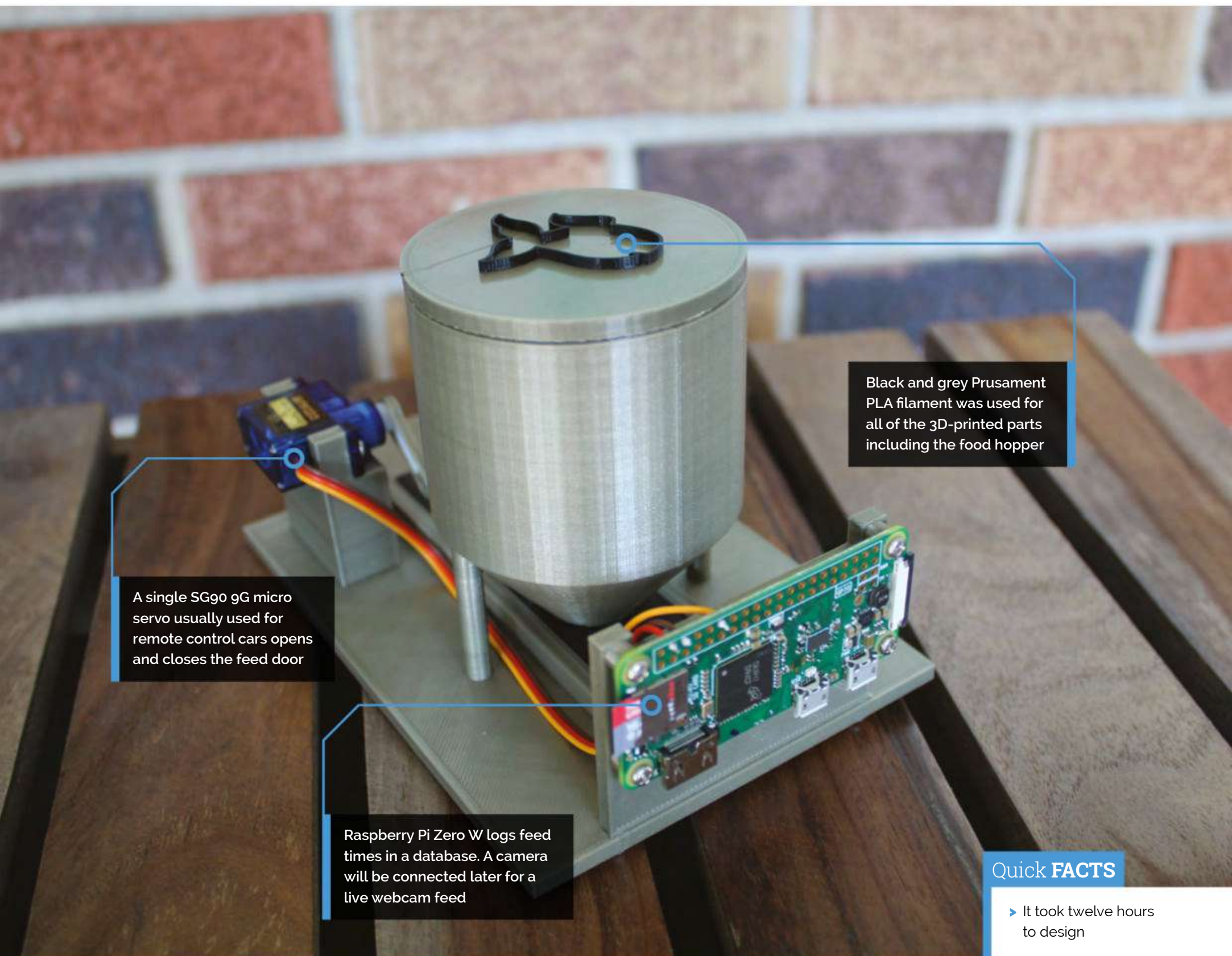
"I also decided to use Raspberry Pi Zero W because it fits all of my design requirements. I needed a way to control the servo and the flexibility to adjust the amount of food dispensed as we add more fish to the tank."

Although Ryan's son doesn't yet have any fish, identifying the ones they'd like to keep played a big part in the design. "Once we get the aquarium set up with the correct water quality and temperature, and once we have established a solid level of healthy bacteria, we plan on purchasing a variety of danios, which are a variety of small tropical fish," Ryan reveals.

“ Ryan's project calls on the Python script two or three times each day ”

"They require food two to three times per day and the amount of food is dependent on the number of fish in the aquarium. It is recommended



**Quick FACTS**

- ▶ It took twelve hours to design
- ▶ The Python script is called three times daily
- ▶ It can work out how much food to give
- ▶ The project cost \$45 to make
- ▶ Ryan is working on a web interface


that no more food be placed in the tank than what the fish can consume in two minutes or less.”

### Feeding the fishes

As such, the database stores the feed times as well as how long the feeder’s door needs to open, and the required servo angle. By making use of scheduled commands (or cron jobs), Ryan’s project calls on the Python script two or three times each day, accessing the database for the most recent feed time. If this was more than seven hours ago, then a correct amount of food is promptly dispensed and a new timestamp is written.

“As fish are added, the door open size and open duration values will need to be adjusted,” Ryan

explains. “By logging feed times in a database for tracking purposes, Raspberry Pi Zero W can also send me an email when the hopper is near-empty. This is based on counting the number of times food has been dispensed, and it lets me know when the food hopper needs to be refilled.”

In the future, Ryan wants to add a limit switch to the door mechanism so the script can detect full and complete door opening and closing. “This would send me an email if there are issues leading to either no food being dispensed or an entire hopper’s worth of food being dropped into the aquarium,” he says. “I also plan to add a live video stream of the aquarium so my son can watch his happy fish swimming around.” 



# Live CTA Railway Map

This live map of Chicago's 'L' rail system lights up stations where a train is approaching. **Phil King** climbs aboard



MAKER

## Jordan von Mulert

Jordan is a violin luthier turned mechanical engineer. His passion is learning and making things. When not with his wife and kids, you'll find him in his workshop or exploring in the woods.

**W**e've seen a few railway-themed Raspberry Pi projects before, including mini departure boards, but Jordan von Mulert has gone one step further by creating a whole railway map – of Chicago's 'L' elevated railway – lit up with LEDs to show the positions of trains at stations in real-time.

Jordan was inspired to make the map after moving away from the Chicago, where he'd lived for ten years with his wife. "Since moving away from the city, we have missed the days of being able to ride the train," he reveals. "Creating this live rail map gives a real sense of connection to the ebb and flow of the city. I like waking up early in the AM and seeing maybe only a dozen trains running in the city. But as the city comes alive, more and more trains light up my map."

## Light up the board

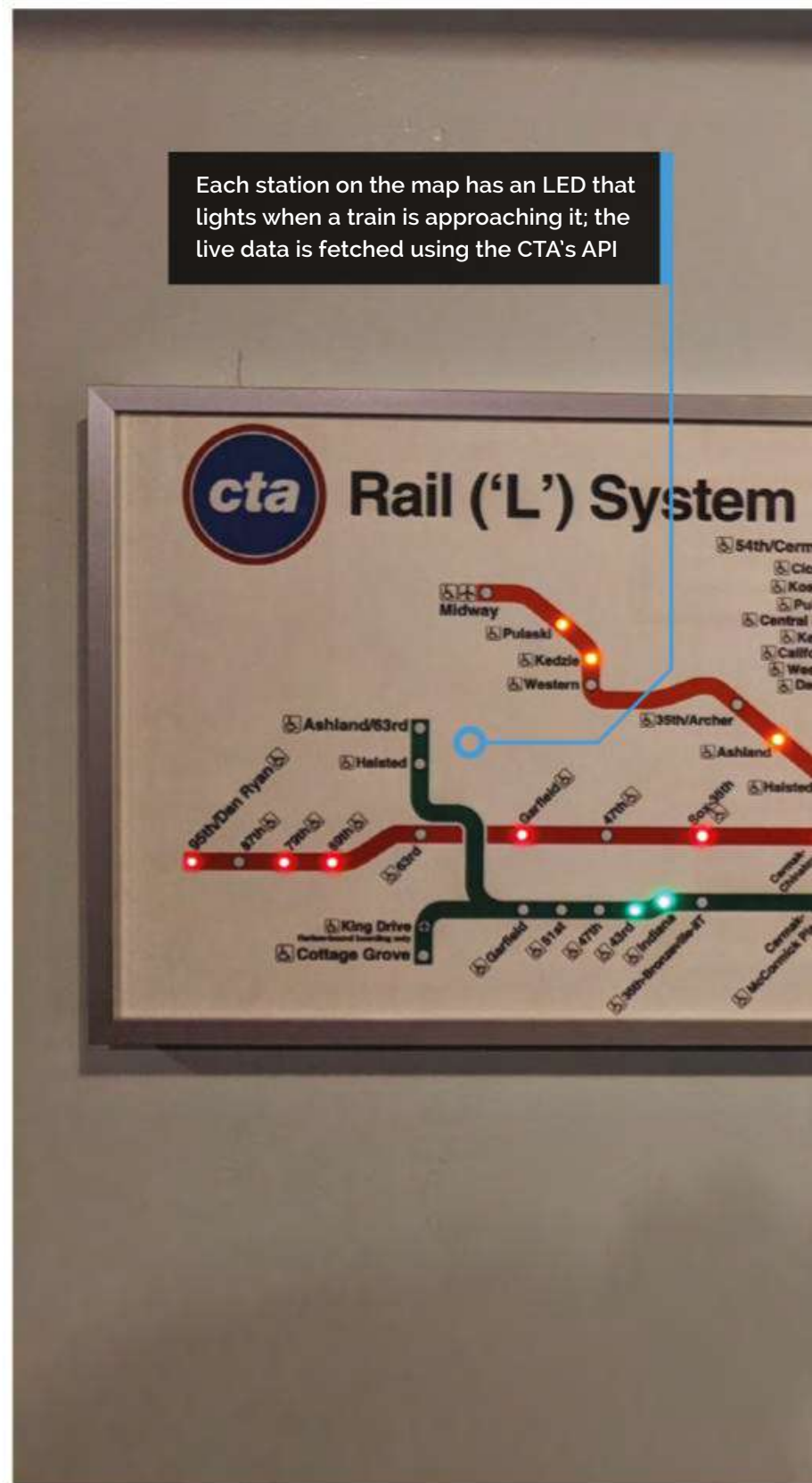
Mounted on a wooden board, the map features no fewer than 191 LEDs – one for each station – wired individually to pins on eight 24-channel PWM LED driver boards controlled by a Raspberry Pi Zero W.

Raspberry Pi is at the heart of the operation, as Jordan explains. "On startup it runs my Python script which pulls data from the CTA API about every seven seconds. I found that more often than that doesn't capture any useful changes, but less often than that and you tend to get lots of changes at once."

The CTA's API gives him a complete status of all the trains operating in the system. "When a train approaches a station, the API includes an 'approaching station' flag for that train," says Jordan. "My code looks for these flags and activates the LED mapped to the corresponding station."

The script will also keep track of each train along its run so that it knows when to turn off the LED for the last station and illuminate the LED for the new

Each station on the map has an LED that lights when a train is approaching it; the live data is fetched using the CTA's API

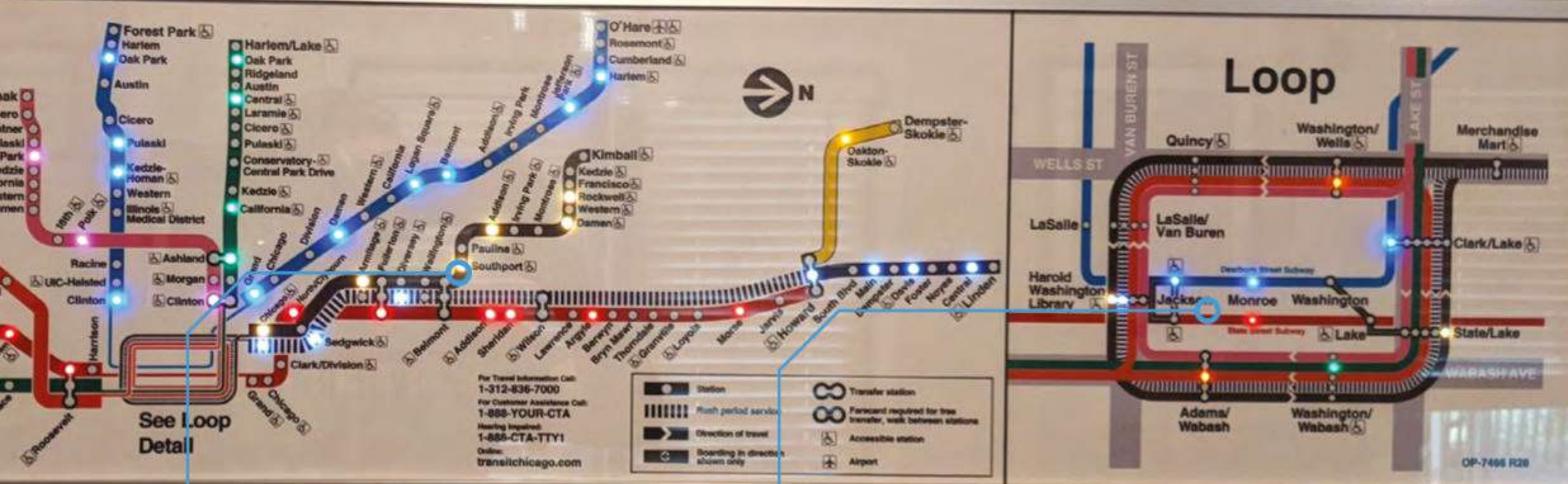


approaching station, and also to know when a train has left service at the end of the run, otherwise the last LED in the run would be perpetually lit.

## Web of wiring

While Raspberry Pi is the brains of the operation, Jordan tells us the eight LED drivers are the brawn of it, as they control each individual LED. "I debated for a long time as to the best way to obtain independent control of the 191 LEDs needed for the map," he recounts. "Addressable LEDs were an option, but finding 3 mm discrete through-hole





Each individual LED is wired separately to one of eight driver boards controlled by a Raspberry Pi Zero W

The map features a zoomed-in view of The Loop, a 1.79-mile long circuit which is one of the world's busiest

### Quick FACTS

- ▶ The railway has 145 stations, but some are on more than one line
- ▶ 191 individual LEDs were required for the project
- ▶ Using a custom PCB would have been very expensive
- ▶ The physical build only took 12 hours...
- ▶ But Jordan spent months brainstorming ways to ease assembly

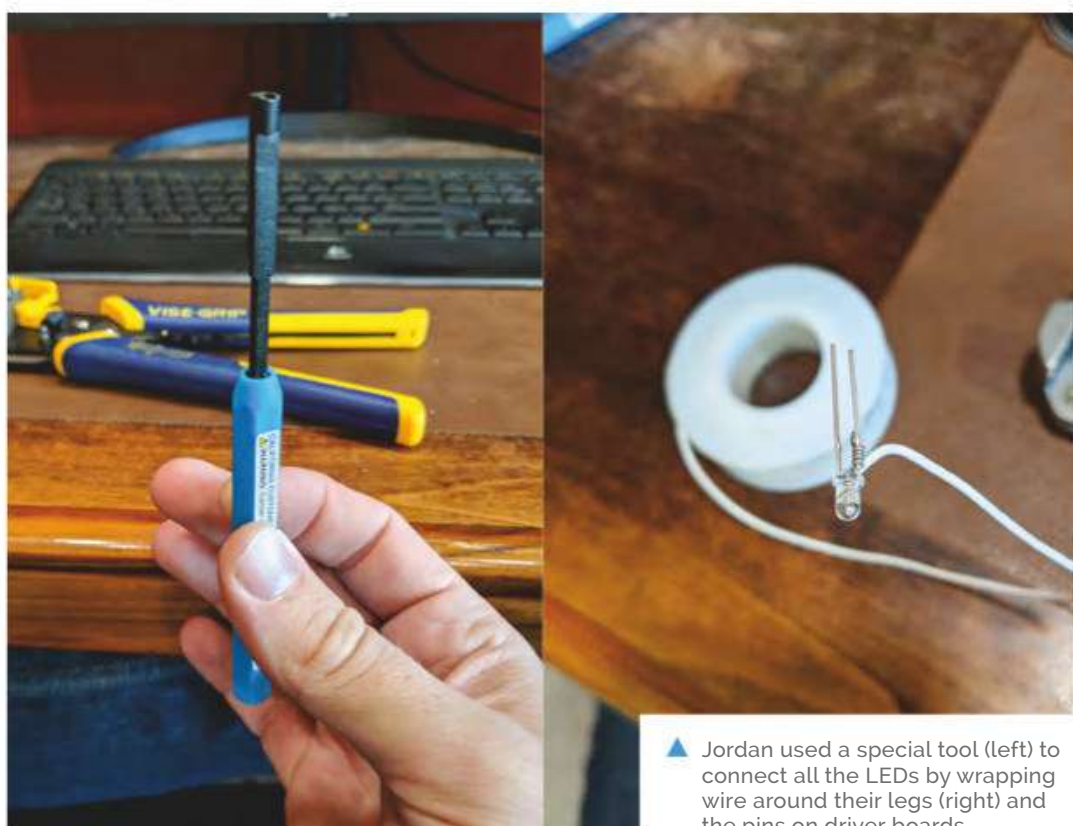
▶ The rear view of the map reveals the incredible feat of wiring each LED individually. The eight PWM driver boards are controlled by a Raspberry Pi Zero W on the right





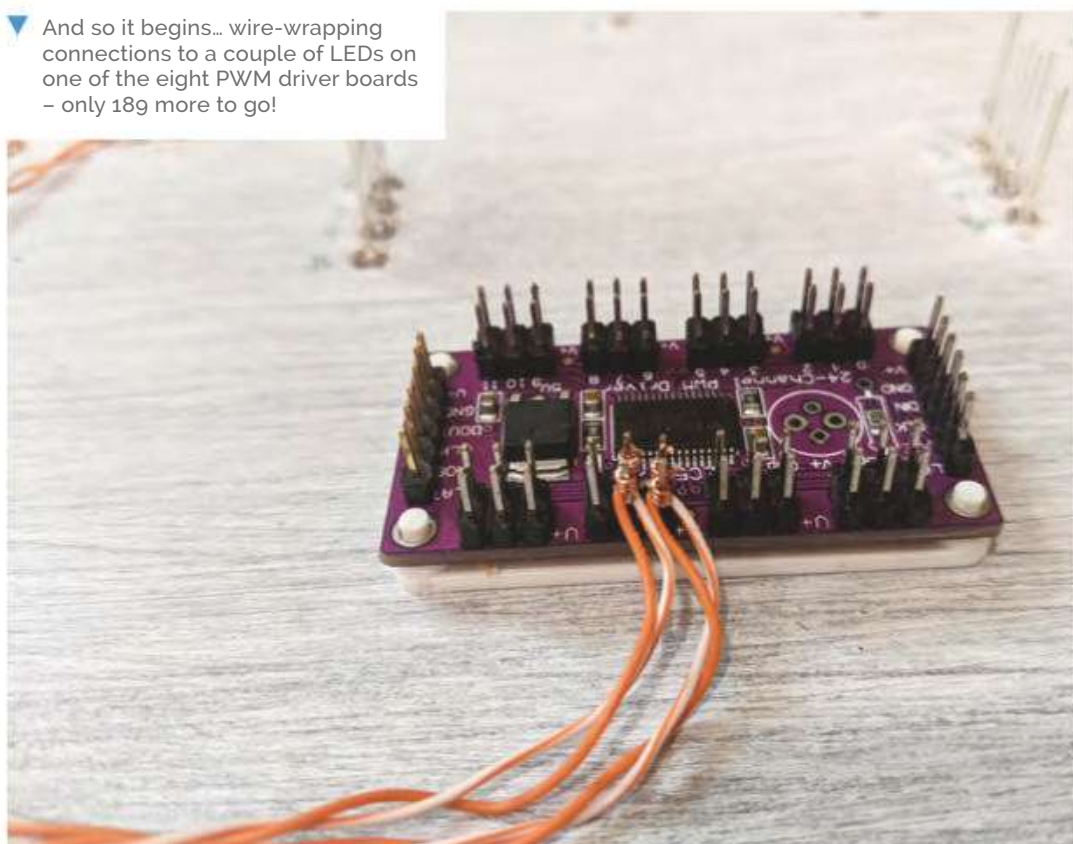


▲ A close-up of Raspberry Pi Zero W mounted on the rear of the map, showing the wire-wrapped connections to its GPIO pins



▲ Jordan used a special tool (left) to connect all the LEDs by wrapping wire around their legs (right) and the pins on driver boards

▼ And so it begins... wire-wrapping connections to a couple of LEDs on one of the eight PWM driver boards – only 189 more to go!



addressable LEDs that could be mounted without a PCB proved to be a challenge. In the end I stumbled across these drivers and determined that they would be workable.”

“As the city comes alive, more and more trains light up my map”

With each LED needing to be connected to one of the driver boards, the project required a phenomenal amount of wiring. Rather than soldering them all, Jordan opted to use wire wrapping, which he says is a lot quicker. “It’s so fast and easy with a tool... and they are super secure! Apparently they used wire wrapping on the Saturn V [rocket] – not to suggest that my wraps were as good as NASA, but in principle they can take a shocking amount of vibration. The other benefit to them is serviceability. I can undo a wire wrap to swap an LED in less than the time it would take my iron to heat up.”

## In the loop

The zoomed-in view of ‘The Loop’ section of the CTA railway caused a little extra complication, and also precluded using off-the-shelf addressable RGB LED string lights for the project. “Those have 5 mm LEDs which would have been too big for the tight spacing required at each train stop,” notes Jordan. “I had considered use different LEDs for that section only, but I wanted the lighting to be consistent.”

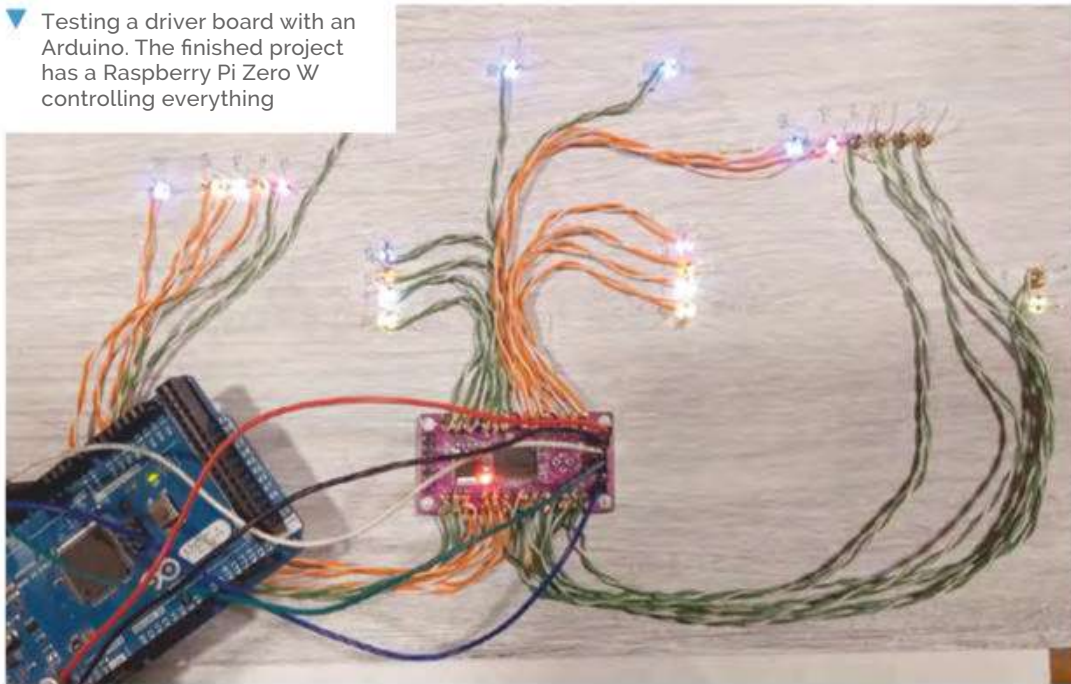
Jordan spent hours debugging code and mapping each LED channel to the correct stop. “Electrically, things went pretty smoothly,” he says. “I ended up adding some optional filter capacitors to the boards to keep electrical switching noise down, and I’m still hunting some gremlins in the SPI data lines. But you know how it is: the reward is the journey, not the end product.”



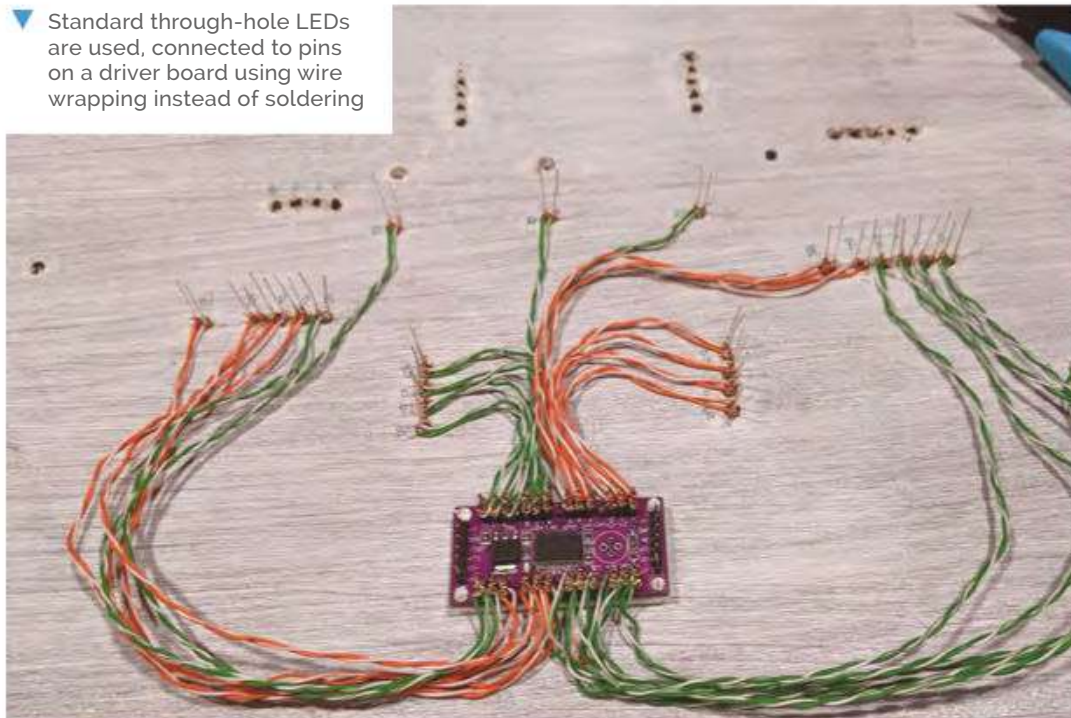


▲ That's a lot of wiring! 191 LEDs are connected individually to eight PWM driver boards

▼ Testing a driver board with an Arduino. The finished project has a Raspberry Pi Zero W controlling everything



▼ Standard through-hole LEDs are used, connected to pins on a driver board using wire wrapping instead of soldering



## Making a map

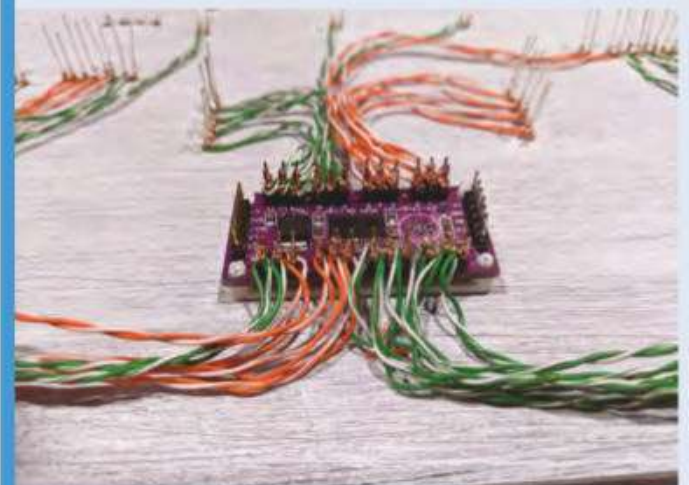
Creating a railway map with holes for the LEDs to light it up.



**01** Jordan bought a translucent map of the CTA rail system and traced the position of each station on a paper template placed over it.



**02** He then transferred the paper template to the wooden mounting board and punched a hole at each station for a 3 mm LED to fit into.



**03** Instead of soldering, wire wrapping was used to connect each individual LED to pins on one of the eight PWM LED driver boards.



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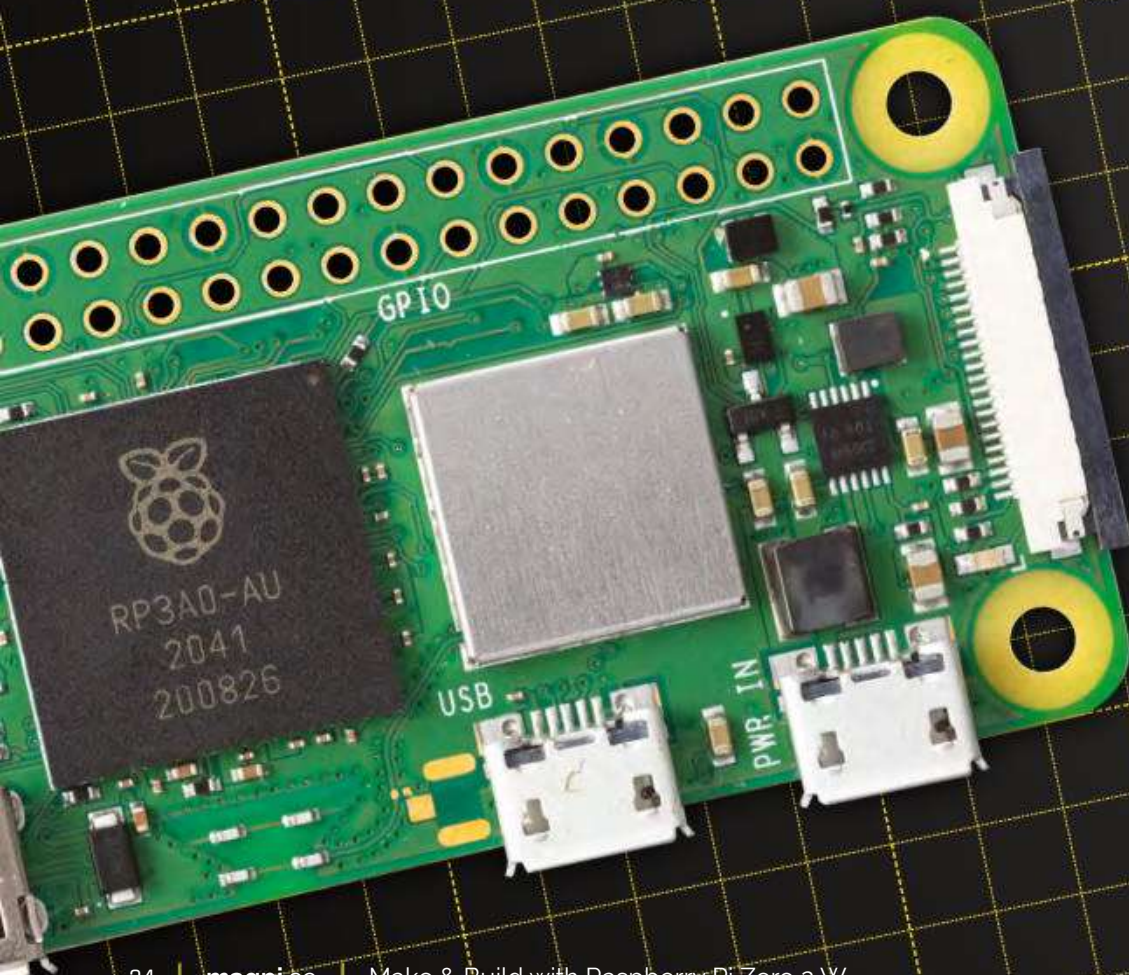

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SEE PAGE 32

# MAKE & BUILD WITH ZERO 2

DISCOVER 40 INCREDIBLE  
RASPBERRY PI ZERO 2 W PROJECTS.  
**BY ROSIE HATTERSLEY**



**B**oasting a quad-core processor running at 1GHz, and with up to five times the processing power of its predecessor, yet with exactly the same footprint, Raspberry Pi Zero 2 W is a great single-board computer to build projects with. The tiny new computer was given away – worldwide – as a free gift to all print and subscription readers of this fine publication. And new subscribers can pick up a free Zero 2 W with a 12-month subscription to *The MagPi* ([magpi.cc/subscribe](http://magpi.cc/subscribe)).

The \$15 wonder is a new and improved entry-level Raspberry Pi model, making good on Raspberry Pi's continuing aim to get the power of computing into the hands of just about everyone, tearing down barriers of cost and geography.

Zero 2 W represents a significant performance boost, should you be thinking of simply updating an existing Raspberry Pi Zero W project. For most people, however, the launch of this diminutive but incredibly able single-board computer is an excuse to begin a whole new Raspberry Pi project. Here, then, are 40 suggestions of ways to make use of your Raspberry Pi Zero 2 W.



# ZERO 2 W

## STARTER PROJECTS

### 01 Raspberry Pi PC Challenge

With a 1GHz quad-core processor, Raspberry Pi Zero 2 W's CPU is every bit as powerful as a Raspberry Pi 3 (albeit with 512MB RAM). Pair your Zero 2 W with a keyboard, mouse, and screen and it can be used as a capable home computer. For a complete rundown of how to use your tiny new Raspberry Pi as a replacement for a much more power- and space-hungry desktop computer, check out our Raspberry Pi 3B+ PC Challenge in *The MagPi* issue #59.

[magpi.cc/59](http://magpi.cc/59)

### 02 Start coding

One big reason many people buy a Raspberry Pi is to pick up some coding skills. And Raspberry Pi OS is packed with programming languages, tools, projects, and tips. Beginners should start with Scratch, a visual language that teaches object-oriented skills. Open Scratch 3 and click on Tutorials to start. For advanced projects, including Python, click Help > Projects.

[magpi.cc/learnscratch](http://magpi.cc/learnscratch)

[magpi.cc/learnpython](http://magpi.cc/learnpython)

### 03 Discover electronics

Using Raspberry Pi and electronics together opens up a whole world of educational and creative possibilities (as the project showcases we feature every issue attest). Armed with a breadboard, jumper leads, LEDs, buzzers, resistors, and switches, you'll be well set for a journey to becoming an inventor. Follow our electronics guide in issue #64.

[magpi.cc/64](http://magpi.cc/64)

### 04 Get retro with RISC OS

A popular project is to (re)discover computers of yesterday. RISC OS was introduced with the Acorn Archimedes, which was designed for the ARM processors that power Raspberry Pi. Many people don't know that RISC OS is still around, in the form of RISC OS Open. This open-source operating system has a tiny footprint and retro feel, but with modern features such as web browsing (you will need an Ethernet adaptor). Find Risc OS in Raspberry Pi Imager under Other General Purpose OS.

[magpi.cc/riscos](http://magpi.cc/riscos)

### 05 Solder GPIO Pins

Get ready for breadboarding and circuit prototyping by attaching a pin header to your Zero 2 W. For a detailed guide to soldering see [magpi.cc/zerosoldering](http://magpi.cc/zerosoldering).

#### Prepare your workspace

You'll need a soldering iron and either lead-based or lead-free solder. Declutter your workspace, open a window to provide ventilation, and don protective gloves and goggles. Attach a 2x20-pin header ([magpi.cc/headers](http://magpi.cc/headers)) to the holes on one side of Zero 2 W. You can use putty or insert Zero 2 W into a breadboard to hold it in place.



**Warning!**  
Hot solder!

Soldering irons get very hot, and stay hot for a long time after they're unplugged. Make sure that you put the iron in the stand when you're not using it and don't touch the metal parts – even after it's unplugged. [magpi.cc/soldering](http://magpi.cc/soldering)

#### Step 1. Heat gently

With the soldering iron safely in its cradle, turn on the power and wait for it to heat up. Tin the tip of the soldering iron with a blob of solder. It's important that the pin and the pad are both heated up, so press the iron against both while you count to three.



#### Step 2. Apply the solder

When you've reached three, still keeping the iron in place, press the end of your length of solder gently against both the pin and pad, but on the opposite side to your iron tip.



#### Step 3. Well-soldered pins

Pull the remaining solder away from the joint, then afterwards remove the iron. You're after a neat mound looking a little like a volcano.





# EASY ZERO 2 W KITS & BUILDS

QUICKLY BUILD A PROJECT BY  
BUYING PARTS AND INSTRUCTIONS

## 06 Pirate Radio

Pimoroni makes some fantastic audio HATs and kits for Raspberry Pi, and the Pirate Audio range add audio output and small screens to Raspberry Pi Zero. They are ideal starter kits for exploring electronics and computing with an audio bent. Use Raspberry Pi Zero 2 W to connect to the internet and tune into radio stations around the world.

[magpi.cc/pirateaudio](http://magpi.cc/pirateaudio)

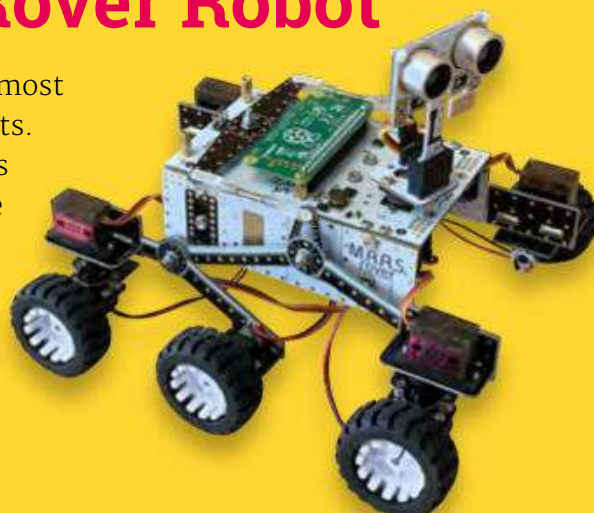


“ These £5 electronics kits are  
absolutely fantastic ”

## 07 M.A.R.S. Rover Robot

Building a robot is one of the most satisfying Raspberry Pi projects. The M.A.R.S. Rover Robot gets top marks for its resemblance to real Mars rovers, with six wheels (four are steerable), terrain-conquering suspension, and a sensor to alert it to obstacles so it can avoid them.

[magpi.cc/marsroverreview](http://magpi.cc/marsroverreview)



## 08 Keybow MINI 3-key

This customisable three-key keypad is ideal for use as a games controller, as play, stop, and pause buttons, or even to steer a robot. The keys have programmable RGB LEDs, and they can also be programmed as shortcut or macro keys.

[magpi.cc/keybowmini](http://magpi.cc/keybowmini)



## 09 CamJam EduKits

These £5 electronics kits in a tin are absolutely fantastic! Developed by the folks at Cambridge Raspberry Jam, they include breadboards, jumper leads, resistors, lights, a buzzer, and worksheets for coding with Python.

[magpi.cc/edukit](http://magpi.cc/edukit)

## 10 AZ-Touch Pi Zero

Making everyday aspects of your home smart gives you something to show for your coding efforts. Zihatec's wall-mountable touchscreen dashboard provides a means of keeping tabs on all those IoT devices that are busy monitoring and metering your water, heating, and power usage. HWHardsoft provides a GitHub page ([magpi.cc/hwhardsoftgit](http://magpi.cc/hwhardsoftgit)), with examples such as a weather station and code lock.

[magpi.cc/aztouch](http://magpi.cc/aztouch)



## 11 Naturebytes

The world around us is fascinating, with the creatures we coexist alongside providing as much interest as those we learn about on TV. Build your own Naturebytes weatherproof wildlife camera, install Raspberry Pi Zero 2 W, and mount it on a tree or post to covertly capture wildlife's secrets.

[magpi.cc/naturebytes](http://magpi.cc/naturebytes)

## 12 OctoCam

Keeping tabs on what's happening in and around your home has never been so simple – or sweet! The 5MP OctoCam has suction pads so it can be mounted almost anywhere and provides a wireless webcam stream and peace of mind. Alternatively, it's great for time-lapse photography.

[magpi.cc/octocam](http://magpi.cc/octocam)



## 13 Unicorn HAT Mini

With 119 separate RGB LEDs the Unicorn HAT Mini turns Raspberry Pi Zero 2 W into a portable lightshow. It's surprisingly versatile: create rainbow displays, scrolling messages, image animations, busy lights, and more. Four buttons enable you to add interaction to your projects.

[magpi.cc/unicornhatmini](http://magpi.cc/unicornhatmini)



## 14 Mood Light

Coding skills come to the fore with this Mood Light kit which challenges you to create gorgeous colour combinations using the Unicorn pHAT and the 32 programmable NeoPixel lights. Once set up, it looks fantastic as a bedroom light, or can be used to set the mood during a party.

[magpi.cc/moodlight](http://magpi.cc/moodlight)

## 15 Pi-hole with PoE USB Hub HAT

The PoE (Power over Ethernet) USB HAT adds three USB-A ports, RJ45 Ethernet for rock-solid networking, alongside an 802.11af router. It's ideal for building self-powered networked projects. We think it'd be the perfect arrangement for setting up a Pi-hole ([magpi.cc/pihole](http://magpi.cc/pihole)), which will protect your network from unwanted adverts and tracking.

[magpi.cc/usbhubhat](http://magpi.cc/usbhubhat)

## 16 Games Console

### Step 1. RetroFlag GPi Case

The RetroFlag GPi Case ([magpi.cc/gpicase](http://magpi.cc/gpicase)) for Raspberry Pi Zero has a total of eight buttons, plus a digital pad and a 2.8-inch 320×240 colour screen. It'll run for hours on three AA batteries, and is small enough to carry in a generously sized coat pocket.

### Step 2. Install RetroPie

Use Raspberry Pi Imager ([magpi.cc/imager](http://magpi.cc/imager)) for Windows, Linux, and macOS to download and write RetroPie (RPI 1/ZERO) on a microSD card. For a more detailed guide to setting up the GPi Case, see *The MagPi* magazine issue #100: [magpi.cc/100](http://magpi.cc/100).

### Step 3. Get some games

You'll need some games to play on your handheld console. Fortunately, there are many homebrew games, along with retro games that have been made publicly available by the original creators. See [magpi.cc/legalroms](http://magpi.cc/legalroms) for a guide to getting games for your retro gaming console.



## 17 Upgrade with Zero 2 W: OctoPrint

OctoPrint is a controller for 3D printers, and OctoPi is a tremendously popular version of it built for Raspberry Pi. Raspberry Pi Zero 2 W is a great upgrade for OctoPrint that provides the computing power that a 3D printer needs. If you're new to the world of 3D printing and making, check out our feature in *The MagPi* magazine issue #97 ([magpi.cc/97](http://magpi.cc/97)).



# ZERO 2 W

## PROJECT TUTORIALS

### 18 Wearable Time-Lapse Camera

This step-by-step walkthrough doesn't just result in a camera you can use to create a series of time-lapse images – it's a wearable device that you can attach to glasses or wear around your neck to automatically capture your day. You can either stream them online wirelessly or create a fancy GIF.

[magpi.cc/timelapse](http://magpi.cc/timelapse)



” Capture how a plant grows over time ”

### 19 Time-Lapse Animations

Watching paint dry or grass grow are usually given as examples of incredibly dull ways to waste time. Time-lapse animations give the lie to this: train your Raspberry Pi Zero 2 W and HQ Camera to capture how a plant grows over time. Seeds growing, clouds moving, and sunrise to sunset are all rewarding examples.

[magpi.cc/timelapseanimations](http://magpi.cc/timelapseanimations)



### 20 LAMP Web Server

Mythic Beasts uses Linux and multiple Raspberry Pi 4 computers to host websites. Using it for a Raspberry Pi-based WordPress blog or site is really straightforward because it has the Raspberry Pi OS already installed. Using LAMP (Linux, Apache, MySQL, and PHP/Perl/Python) server software, your website will be all set to welcome the world.

[magpi.cc/lamp](http://magpi.cc/lamp)

### 21 Do Not Disturb Sign

If you're still working or studying from home, interruptions are probably frequent. Combat intrusions with a not-so-subtle sign showing you need some alone time. This DIY build uses brightly coloured LEDs to show your concentration status, and is a great way to put coding skills to practical everyday use.

[magpi.cc/donotdisturb](http://magpi.cc/donotdisturb)



### 22 Multi-Room Audio System

Learn how to set up the powerful music server Mopidy, and use Python code to play tracks from the main streaming services to enjoy at your leisure. This tutorial then steps things up by making the whole shebang a multi-room experience.

[magpi.cc/multiroomaudio](http://magpi.cc/multiroomaudio)



## 23 Make a 3D Camera

You'll need two Raspberry Pi Zero boards and two Raspberry Pi HQ Cameras for this zany tutorial, one for each eye. The resulting 12.3MP per eyepiece viewer creates 3D effects by placing the two cameras 5cm apart to produce overlapping images that simulate an impressive depth of field.

[magpi.cc/3dcamera](http://magpi.cc/3dcamera)



## 24 Get started with HQ Camera

Raspberry Pi has its own specially designed camera. The incredible 12.3MP HQ Camera attaches to a CS- or C-mount camera lens (the latter with a supplied adapter ring) and via a ribbon cable to a Raspberry Pi, which you'll use to trigger its rolling shutter. Timer delays and video capture are also possible!

[magpi.cc/getstartedhqcam](http://magpi.cc/getstartedhqcam)



## 25 Zero Key Ring

Spontaneous Raspberry Pi fans will like the concept of this take-anywhere option in which a Zero 2 W is kept safely inside a 3D-printed case attached to your key fob, ready for use whenever the need arises. Since the W denotes wireless, you might use it more often than you expect.

[magpi.cc/zerokeyring](http://magpi.cc/zerokeyring)

## 26 NeoPixels

Raspberry Pi Zero 2 W lends itself to wearable projects (builds that you can carry about with you). Our friends over at HackSpace magazine wrote a whole book on wearable projects, and it's packed with ideas for things you can make ([magpi.cc/wearableprojects](http://magpi.cc/wearableprojects)). Lots of projects use NeoPixels as portable lights, which are a great fit for Raspberry Pi Zero. Take a look at Adafruit's NeoPixels page for help on getting started.

[magpi.cc/neopixelspi](http://magpi.cc/neopixelspi)

## 27 Smart Doorbell

See who's ringing your bell before deciding whether to answer it (and if a polite smile is needed) with this smart doorbell and video intercom project. When someone arrives at your door, you get a notification and snap of the caller on your smartphone, so you can choose whether or not to respond.

[magpi.cc/smartdoorbell](http://magpi.cc/smartdoorbell)

## 28 Build a Low-Cost Robot

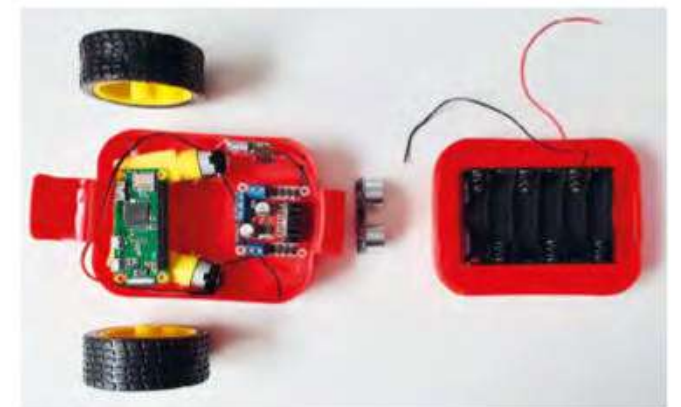
### Step 1. Get the parts

A plastic lunchbox, Raspberry Pi Zero W and an L298 controller plus some AA batteries form the basis of your DIY robot. Our low-cost robot was built by Danny Staple and first appeared in *The MagPi* magazine issue #87 ([magpi.cc/87](http://magpi.cc/87)).



### Step 2. Check the fit

Double-check sketch measurements. Use a fine marker pen to measure and make crosses as hole guides on the lunchbox. Then drill holes and push the axels through. Drill holes to fit your Raspberry Pi Zero and motor controller.



### Step 3. Glue and wire it up

Before gluing and wiring things up, place everything inside the lunchbox case to confirm it will fit and that you have enough leads and jumpers. Follow the online guide to complete the setup ([magpi.cc/robot](http://magpi.cc/robot)).





# ADVANCED RASPBERRY PI ZERO 2 W MAKES

## 29 PolaPi Zero

Instantly printing the photos you take allows you to share the memories with those who were in the picture with you. This Raspberry Pi Zero W build additionally lets you send a copy of the shots you snap to an online photo site, so you can retrieve them whenever you wish.

[magpi.cc/polapizero](http://magpi.cc/polapizero)



## 30 Dride Zero

Dashcam footage is now commonplace, providing drivers and cyclists with eye-witness footage if there's a prang or unexpected incident. Dride sells ready-made dashcams, but there's also a build-your-own option if you prefer to put your Zero to good use.

[magpi.cc/dridezero](http://magpi.cc/dridezero)



## 31 DIY Hardware Password Keeper

So many sites we visit these days require passwords and personal details, that it's tempting to use the same login for them all. A far safer option is to use a dedicated password keeper to generate and store your logins. Here, Raspberry Pi Zero W acts as a separate PC providing those details remotely, where keystrokes can't be logged.

[magpi.cc/passwordkeeper](http://magpi.cc/passwordkeeper)

## 32 RIoT Brick

Smartphone apps and smartwatches can track your fitness moves and cycle rides to measure your performance, but ultra-runner Alan Peaty insisted on a Raspberry Pi Zero version that records the precise weather conditions of his mountain runs, and shares his travails with friends worldwide.

[magpi.cc/riotbrick](http://magpi.cc/riotbrick)

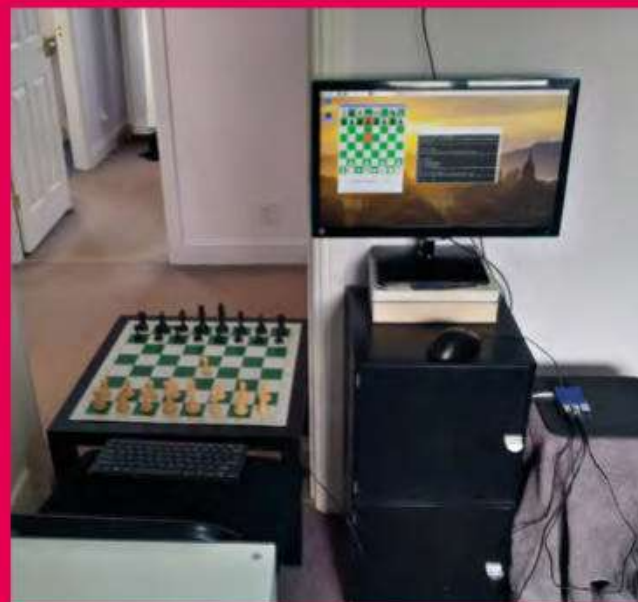


Stargazing and Raspberry Pi go hand in hand

## 33 CamChess

If *The Queen's Gambit* sparked an interest in chess, this challenger setup may also pique your interest: designed to mimic the experience of playing against a real competitor, CamChess uses the Stockfish chess engine and records moves made on a standard chessboard.

[magpi.cc/camchess](http://magpi.cc/camchess)





## 34 RFID Grow Clock

Toddlers who can't yet tell the time can hardly be expected to know whether it's far too early to be up and about. (Hint: yes, kids. It is!) Grow Clock is a fun, visual way of signalling whether it's time to greet everyone, or better to play in your room.

[magpi.cc/rfidgroclock](http://magpi.cc/rfidgroclock)

## 36 Jazz Champion

A repurposed Chess Champion from the 1970s becomes a musical play-and-response game based on chord progressions and the maker's love of jazz. It's a wonderful demonstration of the sort of imaginative builds our readers create with Raspberry Pi Zero W.

[magpi.cc/jazzchampion](http://magpi.cc/jazzchampion)



## 37 Stick PC

USB pen drives are endlessly useful, not least as a carry-with-you backup of files you need. One Raspberry Pi fan set about the task of applying the same idea to his Raspberry Pi Zero W, turning it into a USB stick computer. Genius! Pimoroni now sell a Zero Dongle ([magpi.cc/zerodongle](http://magpi.cc/zerodongle)) if you want a more recent, solder-free solution.

[magpi.cc/stickpc](http://magpi.cc/stickpc)

## 38 Telescope

Stargazing and Raspberry Pi go hand in hand, whether using an HQ Camera or, as in this project, using the free KStars app and a Pi Zero W to enable sky-tracking to be controlled remotely. Follow this build to give an entry-level telescope a serious upgrade for a tiny outlay.

[magpi.cc/telescope](http://magpi.cc/telescope)



## 39 BOSEBerry Pi

Internet radios often take a back seat to smart speakers, but these tend to serve up a narrow choice of services and stations. The BOSEBerry Pi pairs an old iPod speaker dock with a Raspberry Pi Zero W to provide wireless connectivity. The resulting device is in daily use and sounds great!

[magpi.cc/boseberrypi](http://magpi.cc/boseberrypi)



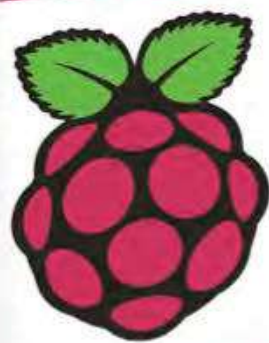
## 40 iPod Classic

If you're lucky enough to be able to lay your hands on an old iPod Classic, upcycle it into a Raspberry Pi Zero 2 W streaming device complete with Spotify playlists. Streaming your music is eminently achievable.

[magpi.cc/ipodclassic](http://magpi.cc/ipodclassic)







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Hacks & Hints



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Spotify Player



BeccaCam  
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# Get started with the Raspberry Pi Build HAT



MAKER

**Lucy Hattersley**

Lucy is editor of *The MagPi* and is taking a much needed break from DIY with actual bricks.

[magpi.cc](http://magpi.cc)

Welcome to the world of LEGO® and Raspberry Pi. Discover how the new Build HAT enables you to build and control brick-based projects

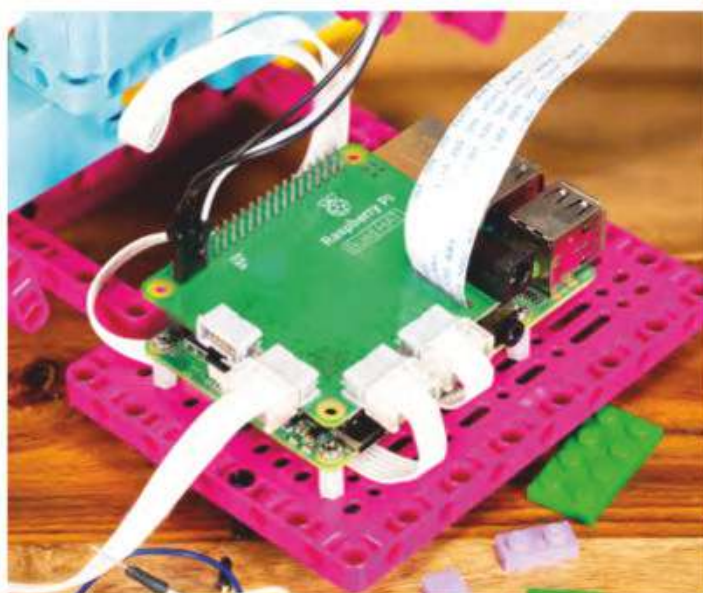
**L**ast month we introduced the new **Raspberry Pi Build HAT**. This new hardware enables you to quickly prototype and build interesting projects with LEGO bricks. The sensors and motors in the SPIKE™ portfolio work fantastically well with Raspberry Pi.

Sitting between the LEGO components and Raspberry Pi is the all new Build HAT. This has four connectors used to attach sensors and motors, bringing your builds to life and enabling sensing input and movement.

We're going to be covering LEGO builds in the following editions of *The MagPi*, and this month we're going to show you how to get started with Build HAT and perform basic motor control, sense position from motors, attach a button, and use a sensor to detect colour.

## You'll Need

- Raspberry Pi  
[magpi.cc/products](http://magpi.cc/products)
- Raspberry Pi Build HAT  
[magpi.cc/buildhat](http://magpi.cc/buildhat)
- Raspberry Pi Build HAT Power Supply  
[magpi.cc/buildhatpower](http://magpi.cc/buildhatpower)
- The LEGO Education SPIKE Prime Set 45678  
[magpi.cc/spikeprime](http://magpi.cc/spikeprime)



▲ This specially designed LEGO Maker Plate™ is the first LEGO element designed to connect to something that isn't another piece of LEGO. A little bit of history in the making

## 01 Set up Raspberry Pi

Start with a fresh installation of Raspberry Pi OS using Imager ([magpi.cc/imager](http://magpi.cc/imager)). We're using the latest Bullseye version of the OS ([magpi.cc/bullseye](http://magpi.cc/bullseye)). While it's copying the software to your microSD card, set up the Build HAT. Attach the 9 mm spacers to the bottom of the board using four screws. Unlike other HATs, the chips and components are on the bottom of the board (so there is space for more HATs and LEGO components). The spacers protrude from the same side as the Build HAT chips and components. Connect the Build HAT to the GPIO pins on Raspberry Pi using the other four screws.

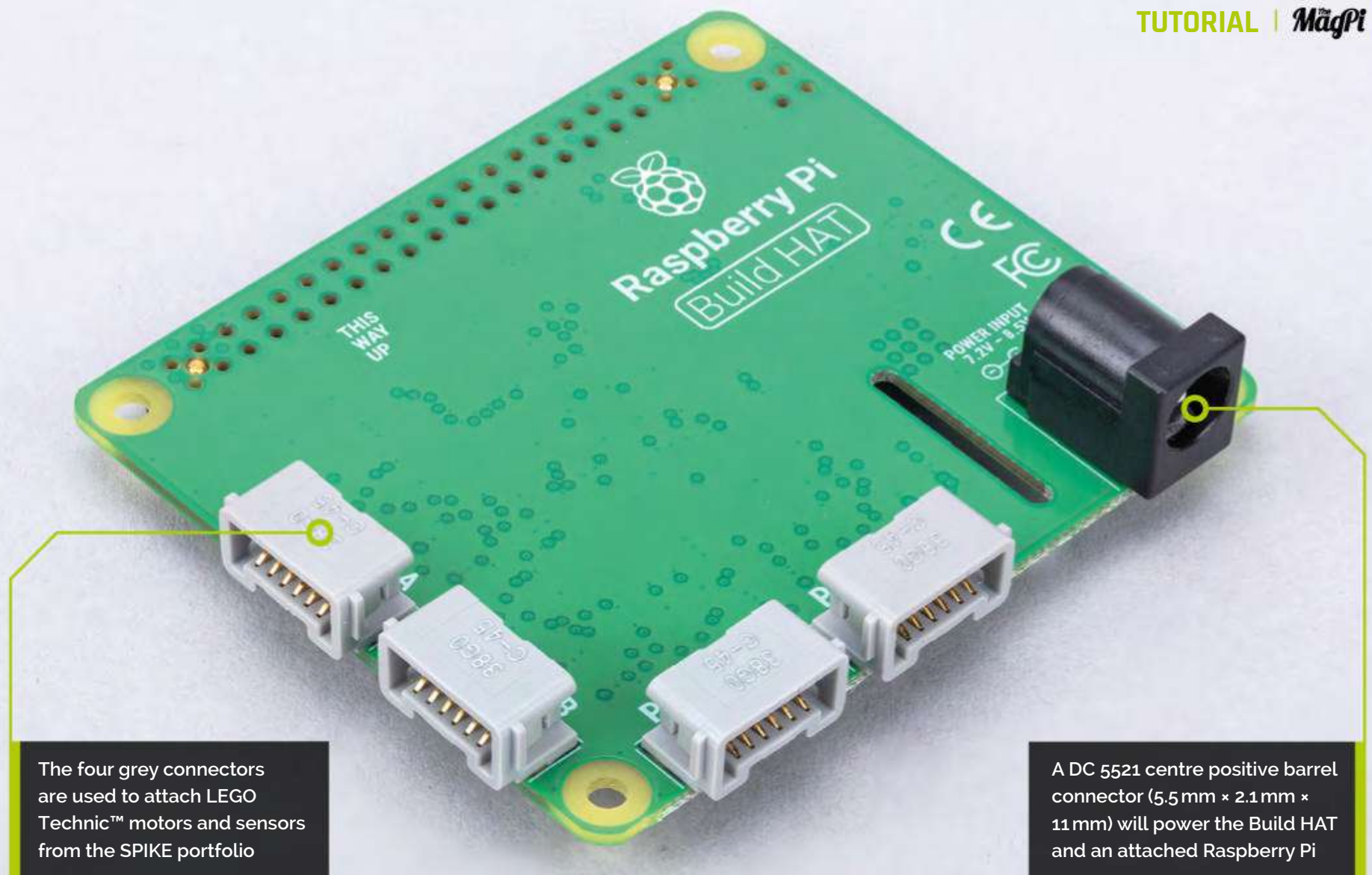
## 02 Power up and set up

Power up your Raspberry Pi using either the Build HAT Power Supply or a regular Raspberry Pi power connection. For the setup process, you should attach a keyboard, mouse, and connect to a display (you can connect remotely via SSH or VNC once set up). Boot into Raspberry Pi OS and follow the setup instructions, connecting to your network and providing a custom password.

## 03 Configuration

When you have completed the Raspberry Pi OS setup process, and rebooted, open the Raspberry Pi Configuration Tool (Menu > Preferences > Raspberry Pi Configuration). Click the Interfaces tab, and set Serial Port to Enabled and Serial Console to Disabled.





## 04 Install Build HAT software

The Build HAT Python library will enable you to control the Build HAT (and connected LEGO components) with code. Open a Terminal window and type:

```
pip3 install buildhat
```

For more information on the Build HAT library, take a look at [magpi.cc/buildhatlibrary](https://magpi.cc/buildhatlibrary).

## 05 Connecting a motor

Now that the Build HAT is set up and connected to Raspberry Pi, we can begin to experiment with motors and sensors.

Connect a motor to Port A on the Build HAT. The connector needs to be inserted the correct way up. If the connector doesn't slide in easily, rotate it by 180 degrees and try again.

Start the Thonny IDE (Menu > Programming > Thonny IDE) and enter the program code from **motor.py** listing.

Click Run. You will be prompted to save the file; call it 'motor.py'. As this is the first time you are running a Build HAT program, there will be a few seconds pause while the firmware copies across to the board. When complete, the red LED on the board will turn off, the green LED will appear, and the motor will turn for five seconds.

### motor.py

> Language: Python

DOWNLOAD  
THE FULL CODE:



[magpi.cc/github](https://magpi.cc/github)

```
001. from buildhat import Motor
002. motor_a = Motor('A')
003. motor_a.run_for_seconds(5)
```

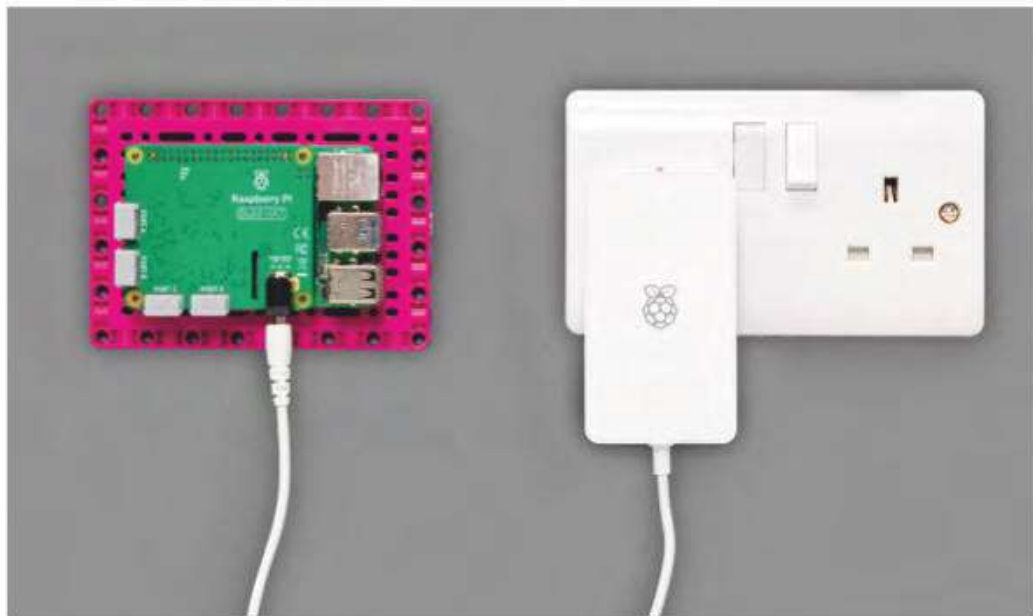
“ The spacers protrude from the same side as the Build HAT chips and components ”

### position.py

> Language: Python

```
001. from buildhat import Motor
002.
003. motor_a=Motor('A')
004.
005. while True:
006.     print("Position: ", motor_a.get_aposition())
```





▲ The Build HAT Power Supply provides 8V DC, 6A output to power both Raspberry Pi and the Build HAT, along with connected motors and sensors

## force\_sensor.py

> Language: **Python**

```
001. from signal import pause
002. from buildhat import Motor, ForceSensor
003.
004. motor = Motor('A')
005. button = ForceSensor('D', threshold_force=1)
006.
007. print("Waiting for button to be pressed fully and
    released")
008.
009. button.wait_until_pressed(100)
010. button.wait_until_released(0)
011.
012. motor.run_for_rotations(1)
013.
014. print("Wait for button to be pressed")
015.
016. button.wait_until_pressed()
017. motor.run_for_rotations(2)
018.
019. def handle_pressed(force):
020.     print("pressed", force)
021.
022. def handle_released(force):
023.     print("released", force)
024.
025. button.when_pressed = handle_pressed
026. button.when_released = handle_released
027. pause()
```

Congratulations, you have a working Build HAT. The next time you run your code, it will not pause for so long.

### 06 Spin it around

Change line 3 of the **motor.py** program and add **speed=50** as an argument.

```
motor_a.run_for_seconds(5, speed=50)
```

Click Run and the motor will run faster. Now change the argument to **-50**:

```
motor_a.run_for_seconds(5, speed=-50)
```

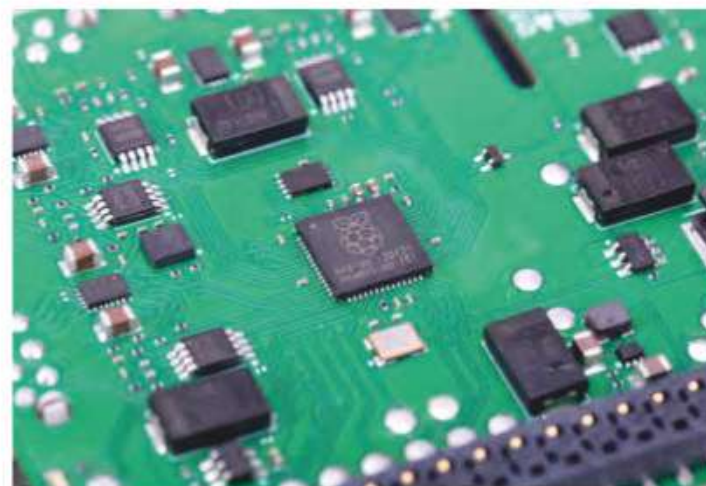
Click Run again and it will run in reverse.

### 07 Get position

LEGO SPIKE Prime motors have a position sensor included to enable precise position. The motors can be used in reverse, as position dials. Click New and enter the code from **position.py**. Click Run and twist the motor around and you will see the position value in Thonny's Shell change from 179 to -180.

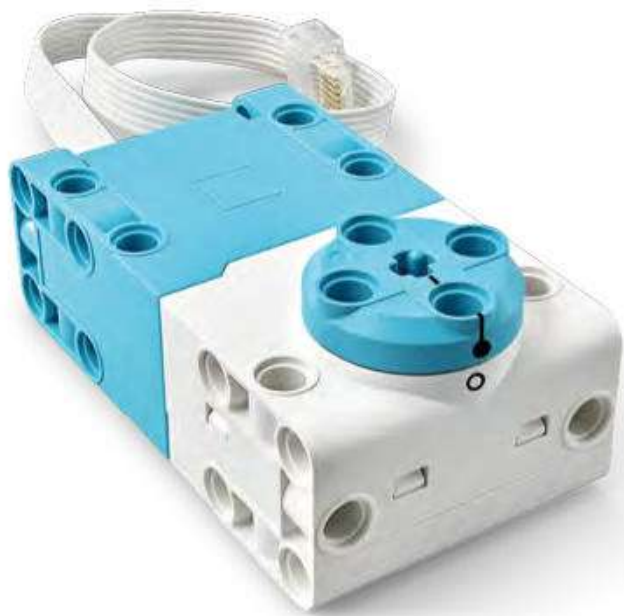
### 08 Attach a button

Let's try a button, or Force Sensor™ as it's known in Brick HAT parlance. With the motor still connected to Port A, connect the Force Sensor to Port D. Click New, and enter the **force\_sensor.py** code.



▲ The Build HAT is unique in that the components are placed underneath the board, enabling LEGO to fit safely on the top. Look closely to spot Raspberry Pi's RP2040 chip introduced with Raspberry Pi Pico





▲ The LEGO Technic motors are very powerful, and you'll need an external 8V power supply (such as the Build HAT Power Supply) to drive them

Run the code and you'll see: "Wait for button to be pressed fully and released". Press the button fully down, and let go. The motor will spin around. The Shell will display "Wait for button to be pressed". Press the button in gently and let go; you will see a "pressed" value appear. Press and release the button to varying strengths to test it out.

## 09 Sensing colour

The Color Sensor™ can sort between eight different colours and can measure reflected and ambient or natural light.

Attach the Color Sensor to Port C on the Build HAT. Create a new file and enter the code from **color\_sensor.py**.

Point the sensor at the green of the Build HAT board and click Run. It should display the HSV, RGBI and other colour values. The code will prompt for

## Top Tip

### Bookmarks

Here are some webpages for you to bookmark as you begin your LEGO journey:

Build HAT documentation  
[magpi.cc/buildhatdoc](http://magpi.cc/buildhatdoc)

Build HAT product brief  
[magpi.cc/buildhatproductbrief](http://magpi.cc/buildhatproductbrief)

Build HAT Power Supply product brief  
[magpi.cc/powersupplyproductbrief](http://magpi.cc/powersupplyproductbrief)

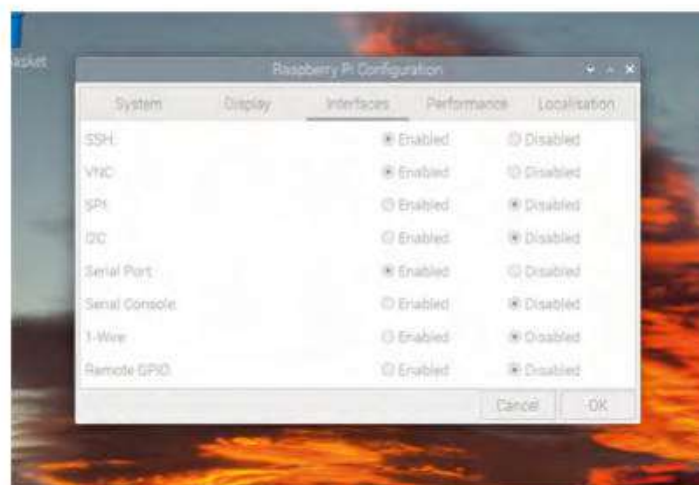
Build HAT Library  
[magpi.cc/buildhatlibrary](http://magpi.cc/buildhatlibrary)

## color\_sensor.py

> Language: **Python**

```
001. from buildhat import ColorSensor
002.
003. color = ColorSensor('C')
004.
005. print("HSV", color.get_color_hsv())
006. print("RGBI", color.get_color_rgb())
007. print("Ambient", color.get_ambient_light())
008. print("Reflected", color.get_reflected_light())
009. print("Color", color.get_color())
010.
011. print("Waiting for color black")
012. color.wait_until_color("black")
013. print("Found color black")
014.
015. print("Waiting for color white")
016. color.wait_until_color("white")
017. print("Found color white")
018.
019. while True:
020.     c = color.wait_for_new_color()
021.     print("Found new color", c)
```

Credit: Chris Richardson



◀ Raspberry Pi Configuration settings for Build HAT

the colour black; move the sensor to a black object (LEGO bricks work well). Then do the same again for a white object. Then the code displays the colour of the objects you point the Color Sensor towards.

## 10 Test out other sensors

This is just the start of what you can achieve with the Build HAT. Over the next few issues we will look at some incredible projects and builds that you can make with LEGO and Raspberry Pi.

In the meantime, read the documentation for the Build HAT Python library to discover more code to test out the components found in the LEGO SPIKE Prime education kit ([magpi.cc/buildhatlibrary](http://magpi.cc/buildhatlibrary)).

## Top Tip

### Notification

When you first attach Build HAT to Raspberry Pi OS Bullseye, you may get a notification alert that the HAT isn't supported. These will vanish when the firmware is uploaded to Build HAT (during Step 5).



# Explore the sensory world: Make an intruder alarm

Catch intruders red-handed with this sound- and laser-triggered alarm



**Phil King**

Long-time contributor to *The MagPi*, Phil is a freelance writer and editor with a focus on technology.

@philkingeditor

**In this series, we are exploring some of the most commonly available sensors and their use cases.** Following last month's fire and gas safety alarm, this time we'll use sensors to build a different kind of alarm: one to detect intruders.

While there are many possible ways to sense the presence of a person nearby, including a PIR motion sensor or camera, we'll be using a laser beam and sound sensor. When either is triggered, a visual and audible alert will go off.

## 01 Connect laser sensor

Think of all those movies where a secret agent or thief has to get past some lasers guarding an object: break the beam and the alarm will go off. That's what we'll be doing here.

For this tutorial, we're using the laser sensor from the Waveshare Sensors Pack, available in the UK from The Pi Hut ([magpi.cc/wavesensors](http://magpi.cc/wavesensors)), and also sold separately, but any similar sensor should work in a similar way.

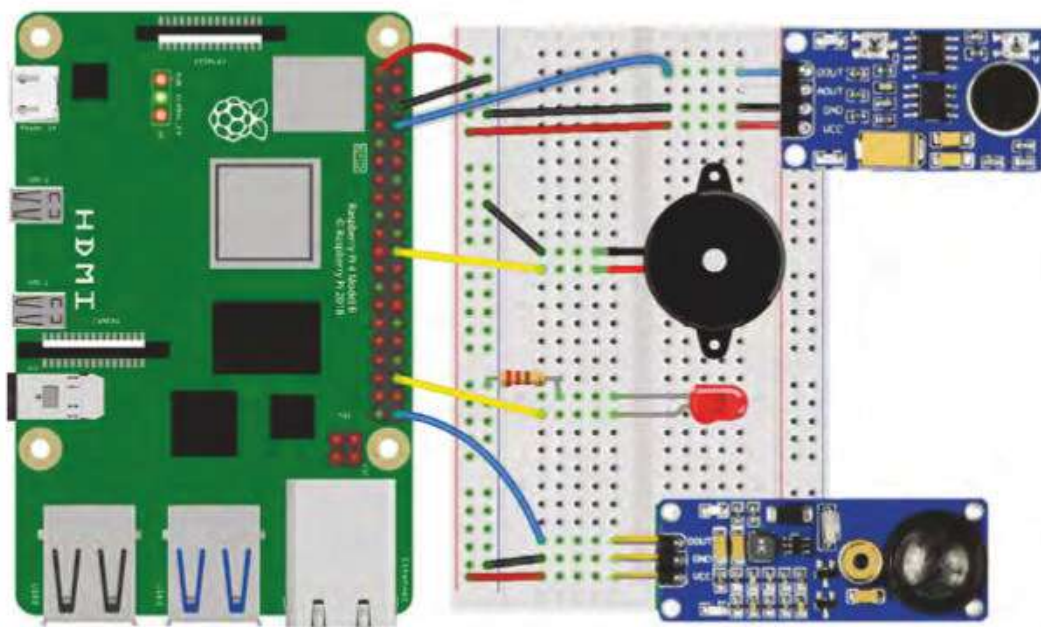
It continually emits a laser beam, and its receiver only detects a reflected beam of the exact same wavelength (650 nm), so it won't be triggered by other visible light. When it detects the beam, its digital pin outputs 1; when the beam is broken, it's 0.

With the power turned off, connect the laser sensor to Raspberry Pi as in **Figure 1**. We're powering it from Raspberry Pi's 3V3 pin, grounding it with a GND pin (both via the breadboard side rails), and the digital output (marked DOUT on the sensor) is going to GPIO 21.

## 02 Laser positioning

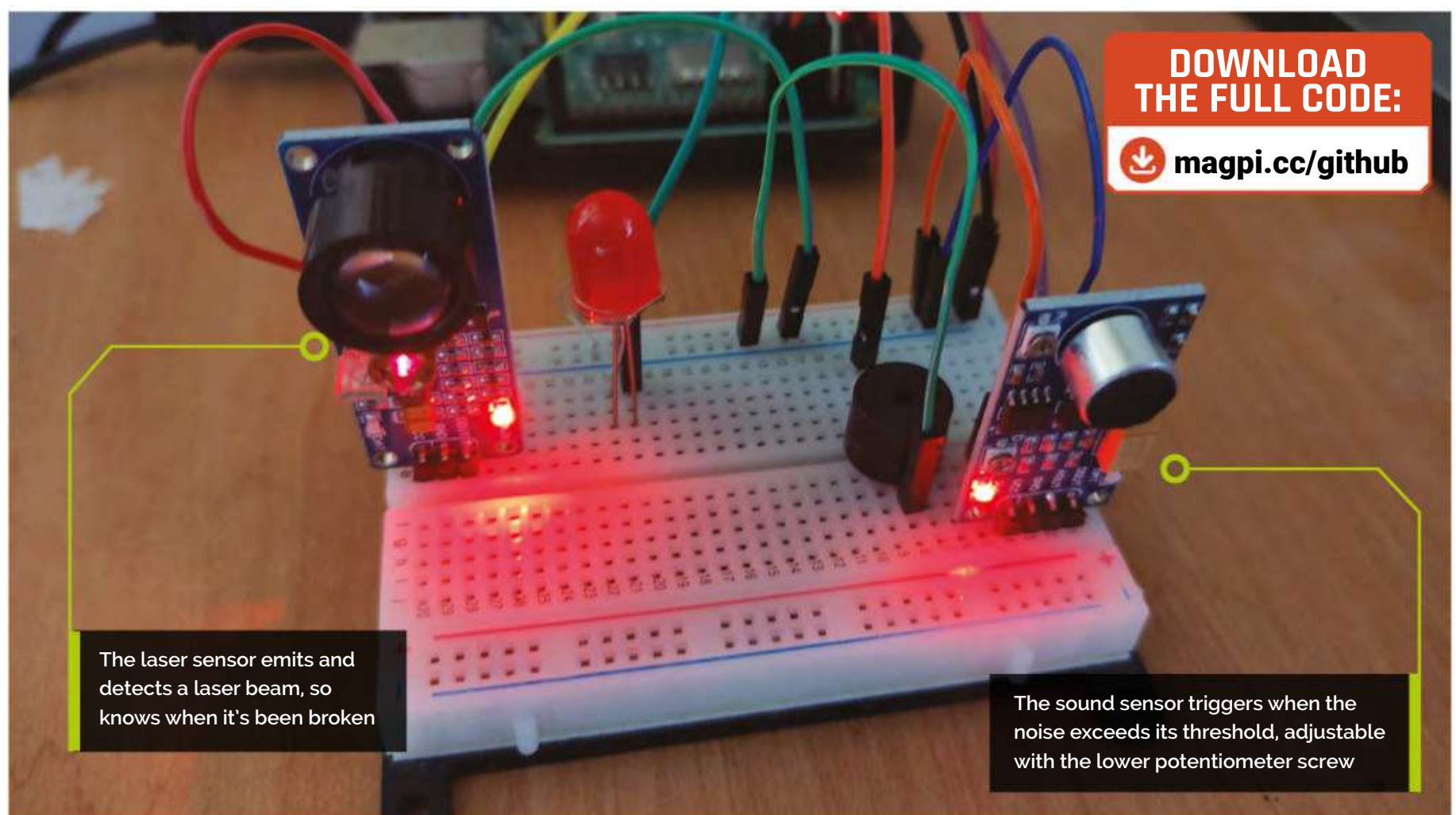
With the laser sensor wired up, turn on Raspberry Pi. You should see the sensor's red power LED (on the right) light up if it's connected correctly. It should also be emitting a laser beam from the metal tube, so be careful never to look straight into it.

Aim the beam at a nearby wall (up to 1.5 m away) and check that its left LED (marked DAT) is lit, confirming that it is detecting the laser beam. You may need to adjust the vertical and horizontal tilt of the sensor, or move it closer to the wall. For the finished alarm, we recommend you place the laser sensor fairly near the floor so that anyone walking through it will break the beam and it won't be anywhere near their eyes.



**Figure 1** The wiring diagram for the complete alarm system, including laser and sound sensors, LED, and buzzer





### 03 Laser test

To begin, we'll create a simple Python program, as in the **laser\_test.py** listing, to read the sensor's digital output and print out a message to show when the beam is broken. From the desktop menu, go to Programming and open the Thonny IDE to start coding.

“ Try breaking the beam with your hand and see if the message changes ”

As before, we're using the GPIO Zero library; at the top of the code, we import the Button method from it. We'll use this to sense when the digital output from the sensor is high, in effect the equivalent of a push-button being pressed. As it's connected to GPIO 21, we assign the laser object to this with **laser = Button(21)**.

In an infinite **while True:** loop, we check whether the pin is low (**if laser.value == 0**), which means the beam has been broken, and set the message (**msg1** variable) that we'll be printing to the Shell area accordingly. In our print statement, we add the **end = "\r"** parameter so the message is always printed on the same line.

Run the **laser\_test.py** code and then try breaking the beam with your hand and see if the message changes to 'Intruder!'. You may find that it works better with your hand more distant from

the sensor. Even if the DAT LED only flickers off momentarily, that should be enough to trigger our alarm later.

### 04 Add a sound sensor

Now that we have our laser sensor working, let's make our setup even more intruder-proof by adding a sound sensor. We're using a Waveshare sound sensor for this, as featured in the Sensors Pack, but other similar sensors are available, along with USB mics.

Our sensor has pins for analogue and digital outputs, but we only need the digital output for our alarm. With the power turned off, we connect that pin (DOUT) to GPIO 14, and the VCC and GND pins to 3V3 and GND (shared with the laser sensor via the breadboard side rails), as in **Figure 1**.

Turning Raspberry Pi back on, you'll see the power LED on the left of the sound sensor is lit up. Make a loud noise and you should see the LED on the right light up to show it has been detected.

### 05 Sound test

Let's create a similar program to test the sensor. In the **sound\_test.py** code listing, we assign the **sound** object to GPIO 14 with **sound = Button(14)**. Again, we use the Button method to detect when the pin is triggered.

### You'll Need

- Laser sensor  
**magpi.cc/lasersensor**
- Sound sensor  
**magpi.cc/soundsensor**
- LED
- Active piezo buzzer
- Jumper wires



**Danger!**  
Laser

The laser sensor used here continually emits a laser beam. Be very careful not to point it towards anyone's head as it could potentially damage their eyesight.

**magpi.cc/lasersafety**



## Top Tip



### Off board

We've placed our sensors on the breadboard, but you could keep them separate from the other components and wire their digital outputs directly to the GPIO pins. It's best to keep the laser sensor vertical, however, so that its beam stays horizontal.

This time in our `while True:` loop, we test whether the pin is high (there is a loud enough noise to trigger the sound sensor). As before, this determines which message (in the `msg1` variable) is printed to the Shell area.

## 06 Make a noise

Now it's time to test our sound sensor to check it's wired up and working correctly. Run the `sound_test.py` Python code and then made a loud noise to make the DAT LED on the right of the sensor light up. You may find that you need to be noisy for a second or so and that there's a short delay before the message changes briefly from 'All clear' to 'Intruder!'.

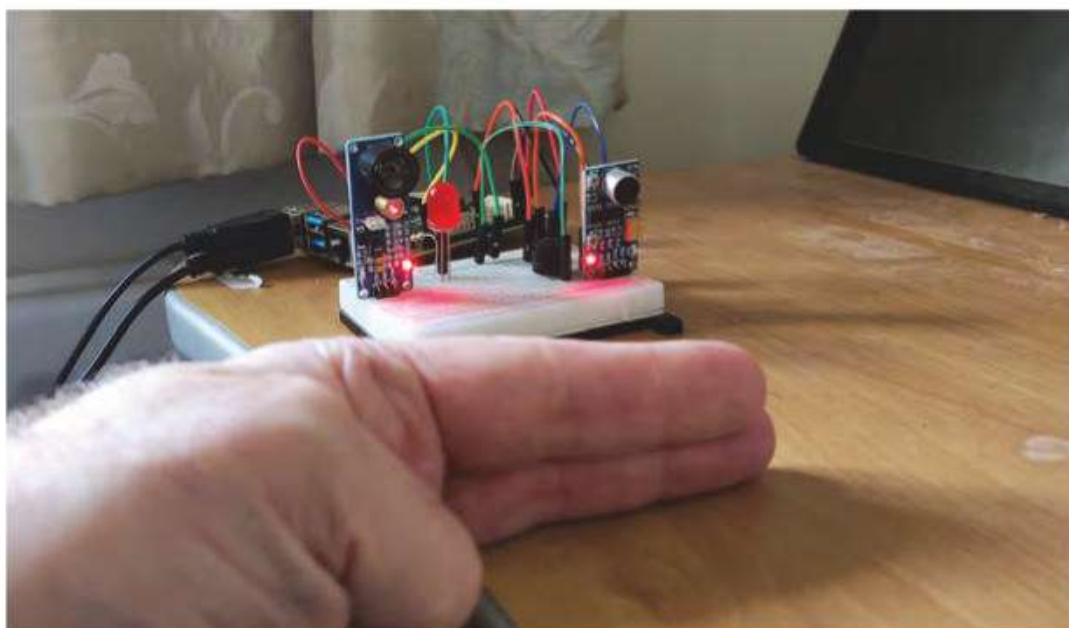
If you're having trouble triggering it, try altering the sensitivity of the sound sensor by adjusting the lower potentiometer screw (marked D for digital) on it: turning it anticlockwise increases the sensitivity, but don't overdo it or the DAT LED will be lit up constantly.

## 07 Add a visual alert

If your sensors and code are working correctly, it's time to move on to the next part. Printed messages are all very well, but for a proper alarm you need a visual and/or audible alert.

As in last month's guide, we'll add a standard red LED for a visual alert. Ours is 5 mm, but you can use a different size. As always, a resistor is needed to limit the current to the LED to ensure it doesn't receive too much and potentially burn out. With the LED placed in the breadboard, with

Testing the laser sensor by breaking the beam. Be careful not to point the laser near anyone's head



## sound\_test.py

> Language: Python

```
001. from gpiozero import Button
002.
003. sound = Button(14)
004. msg = ""
005.
006. while True:
007.     if sound.value == 1:
008.         msg = "Intruder!"
009.     else:
010.         msg = "All clear"
011.     print(msg, end = "\r")
```

legs in different unconnected rows, we connect a 330 Ω resistor between the negative (shorter) leg and the ground rail of the breadboard. The positive (bent, longer) leg is connected to GPIO16 on Raspberry Pi, as in the **Figure 1** wiring diagram.

## 08 Sound the alarm

For our audible alert, we'll use a small active piezo buzzer to make a beeping noise. You could use something else to sound the alarm.

“ This time we've kept it simple with a single alarm function ”

The buzzer has a longer positive leg and a shorter negative one; their positions may also be marked on its top. Connect the negative pin to the breadboard's ground rail and the positive pin to GPIO 25 (as in **Figure 1**).

## 09 Alarm code

With everything wired up as in **Figure 1**, you're now ready to program your intruder alarm. In the final code, `intruder_alarm.py`, we add LED and Buzzer to the gpiozero imports at the top. We also import sleep from the time library, to use as a delay.

If you wanted, you could create a separate function with a different message for each alarm (like our fire and gas alarm last issue), but this time we've kept it simple with a single alarm function,



# laser\_test.py

► Language: Python

```
001. from gpiozero import Button
002.
003. laser = Button(21)
004. msg = ""
005.
006. while True:
007.     if laser.value == 0:
008.         msg = "Intruder!"
009.     else:
010.         msg = "All clear"
011.     print(msg, end = "\r")
```

as we're not bothered how an intruder is detected. When triggered, this executes a `for` loop which toggles the LED and buzzer on and off a set number of times, with a 0.5 sleep delay each time.


In a `while True:` loop, we check the pin values from both sensors and trigger the alarm when the laser beam is broken (`laser.value == 0`) or the sound threshold is exceeded (`sound.value == 1`). If neither is triggered, we show the default message and ensure the LED and buzzer are turned off.

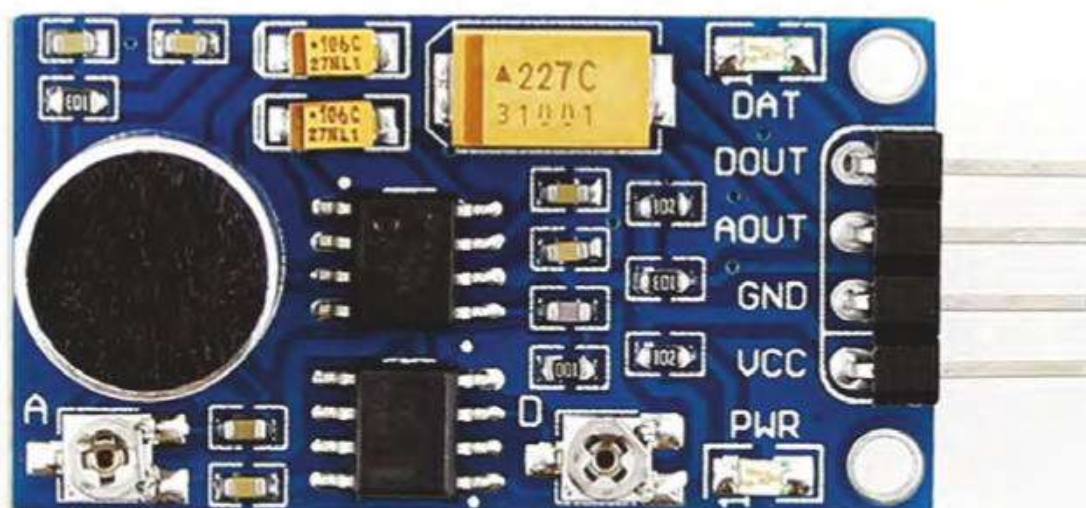
## 10 Test the alarm

Now to test the alarm system. As before, try breaking the laser beam: the LED should then blink and the buzzer will beep. Do the same for the sound sensor by making a prolonged loud noise; the alarm will trigger again. Each time, the 'Intruder!' message will show in the Shell area.

## Taking it further

We now have a simple intruder alarm. To improve it, you could add extra sensors such as a PIR or even a camera to detect movement. You could trigger a larger light and/or play an alert sound or spoken message on a connected speaker. You could also send an email or push notification alert to your phone whenever the alarm is triggered.

Next time we'll create a weather station using temperature, humidity, and ultraviolet light sensors. See you then. 



# intruder\_alarm.py

► Language: Python

```
001. from gpiozero import Button, LED, Buzzer
002. from time import sleep
003.
004. laser = Button(21)
005. sound = Button(14)
006. led = LED(16)
007. buzzer = Buzzer(25)
008.
009. def alarm():
010.     print("Intruder alert!", end = "\r")
011.     for i in range(10):
012.         led.toggle()
013.         buzzer.toggle()
014.         sleep(0.5)
015.
016. while True:
017.     if laser.value == 0 or
018.        sound.value == 1:
019.         alarm()
020.     else:
021.         print("All clear", end = "\r")
022.         led.off()
023.         buzzer.off()
```

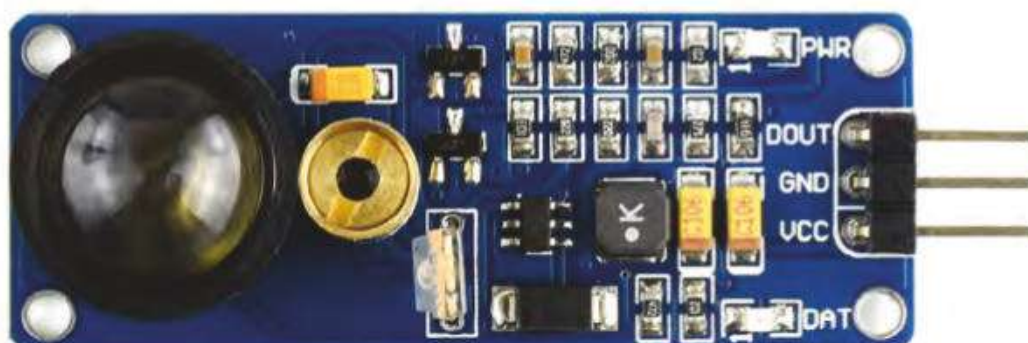
▲ The Waveshare sound sensor. Its sensitivity can be altered by adjusting the A (analogue) or D (digital) potentiometer screw

## Top Tip

### Analogue out

For simplicity, we've used the digital output of the sound sensor to trigger our alarm. To use the analogue output, you'll need to add an ADC chip (e.g. MCP3008) to convert its signal to a digital reading. We'll cover how to use an ADC in the next instalment.

▼ The Waveshare laser sensor. The lens for the receiver is on the left, with the metal laser tube just to the right of it





# Overclock

## Raspberry Pi Zero 2 W



MAKER

**Lucy Hattersley**

Lucy is editor of *The MagPi* magazine and eggs her little Raspberry Pi to run at ever faster speeds. If only she could run this fast!

[magpi.cc](http://magpi.cc)

Give Raspberry Pi Zero 2 W a speed boost by setting overclock settings in the config.txt document

**R**aspberry Pi Zero 2 W has a powerful Cortex-A53 quad-core processor running at a default speed of 1GHz. It is possible to give this a boost up to 1.2GHz, or even 1.4GHz. The extra speed makes Raspberry Pi OS more snappy, and comes in useful when setting up Zero 2 W projects that are a little more demanding and could use a little push (such as image processing or retro gaming). There is a chance, however, that Raspberry Pi Zero 2 W will start to overheat and throttle back the CPU, keeping it safe but making Raspberry Pi OS slower.

As with all overclocking projects, it's important to consider a cooling solution for Raspberry Pi. Overclock is fun to experiment with, however. So let's give Zero 2 W a bit more zest.

▼ We put our Raspberry Pi Zero 2 W inside a FLIRC Raspberry Pi Zero Case, which dissipates excess heat across the metal



### 01 Cool your Zero 2 W

We're going to place Raspberry Pi Zero 2 W inside a FLIRC Raspberry Pi Zero Case (£13/\$18, [magpi.cc/flirczero](http://magpi.cc/flirczero)). The metal case acts as a heatsink. For a cheaper option, attach a Heatsink for Zero 2 W (£1/\$1, [magpi.cc/zero2heatsink](http://magpi.cc/zero2heatsink)).

### 02 Update Raspberry Pi OS

Make sure you are running the latest version of Raspberry Pi OS. Open a Terminal and enter the following:

```
sudo apt update
sudo apt full-upgrade
```

Now reboot the system:

```
sudo reboot
```

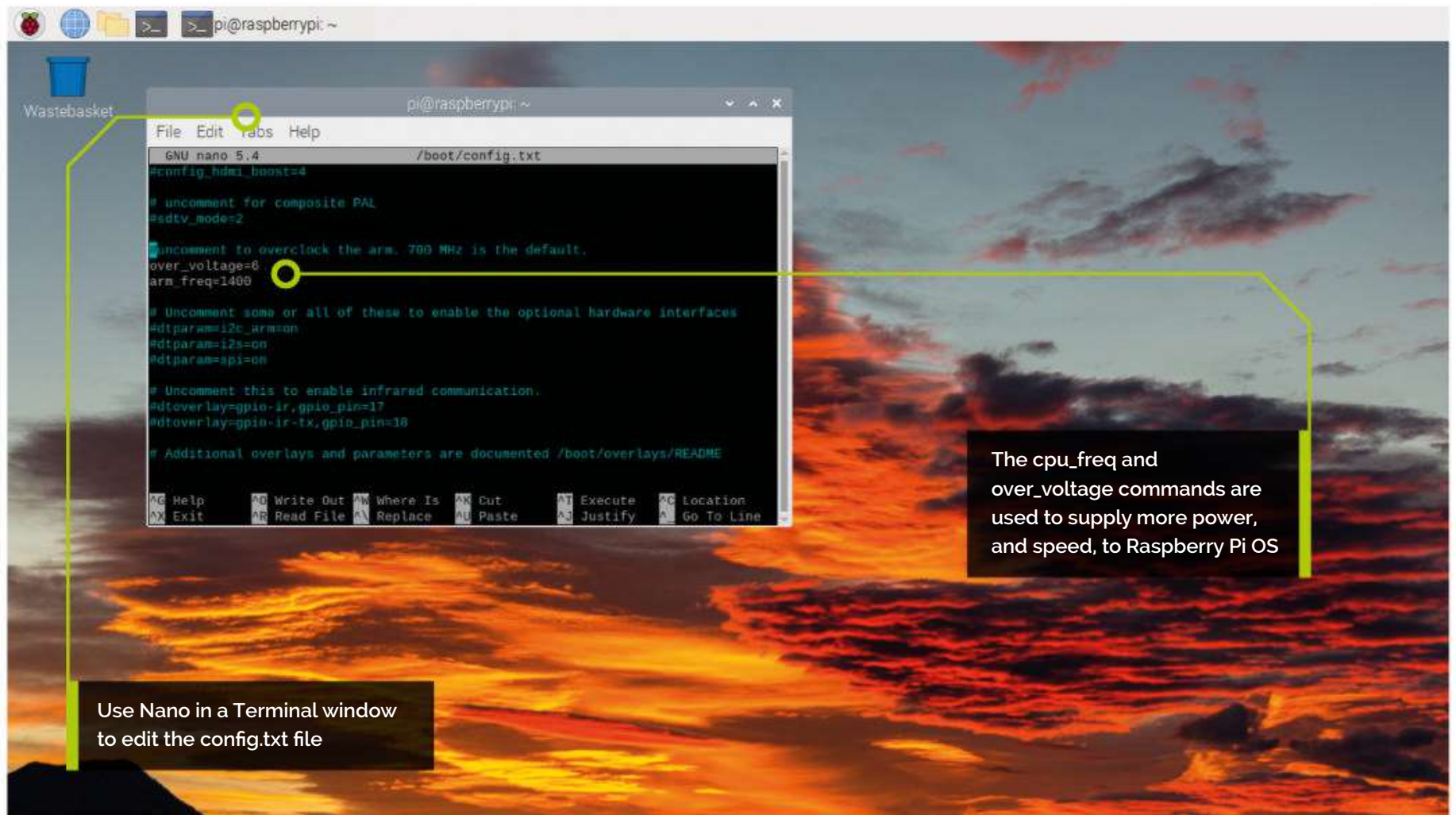
### 03 Watch your speed

Before we start overclocking, take a look at the default CPU speed. Open a Terminal window and enter:

```
vcgencmd measure_clock arm
```

Terminal will most likely return 600000. Divide this result by 1000 and you'll get the speed in MHz. This is the base speed: 600MHz (or 0.6GHz). This is the speed requested by the kernel. If your Raspberry Pi is being throttled due to low voltage or over-temperature, the actual CPU speed may be lower.





## 04 Update config

We're going to use the **config.txt** file to set a new upper limit for the clock frequency. Open another Terminal window and enter:

```
sudo nano /boot/config.txt
```

Scroll down to the section marked:

```
#uncomment to overclock the arm. 700 MHz is
the default.
#arm_freq=800
```

And change the settings to:

```
# Overclock settings
# over_voltage=6
arm_freq=1200
```

The **over\_voltage** command adjusts the core CPU/GPU voltage, and accepts figures between -16 and 8. The default value is 0. The latest firmware in Bullseye will do its best to figure out the correct voltage for an overclock, so we have left **over\_voltage** commented out for now (more info at [magpi.cc/bullseyebonus](https://magpi.cc/bullseyebonus)). Save the file with **CTRL+O** (press **RETURN**) and use **CTRL+X** to exit.

## 05 Restart your Raspberry Pi.

Restart your system to run under the new configuration:

```
sudo reboot
```

When the system starts up again, watch **vcgencmd** again to see your new, faster clock speed in action:

```
watch -n 1 vcgencmd measure_clock arm
```

Browse a few webpages and you'll see speeds of around 1200000000 (or 1.20GHz).

## You'll Need

- ▶ Raspberry Pi Zero 2 W  
[magpi.cc/zero2w](https://magpi.cc/zero2w)
- ▶ Raspberry Pi OS  
[magpi.cc/raspberrypios](https://magpi.cc/raspberrypios)
- ▶ config.txt  
[magpi.cc/configtxt](https://magpi.cc/configtxt)

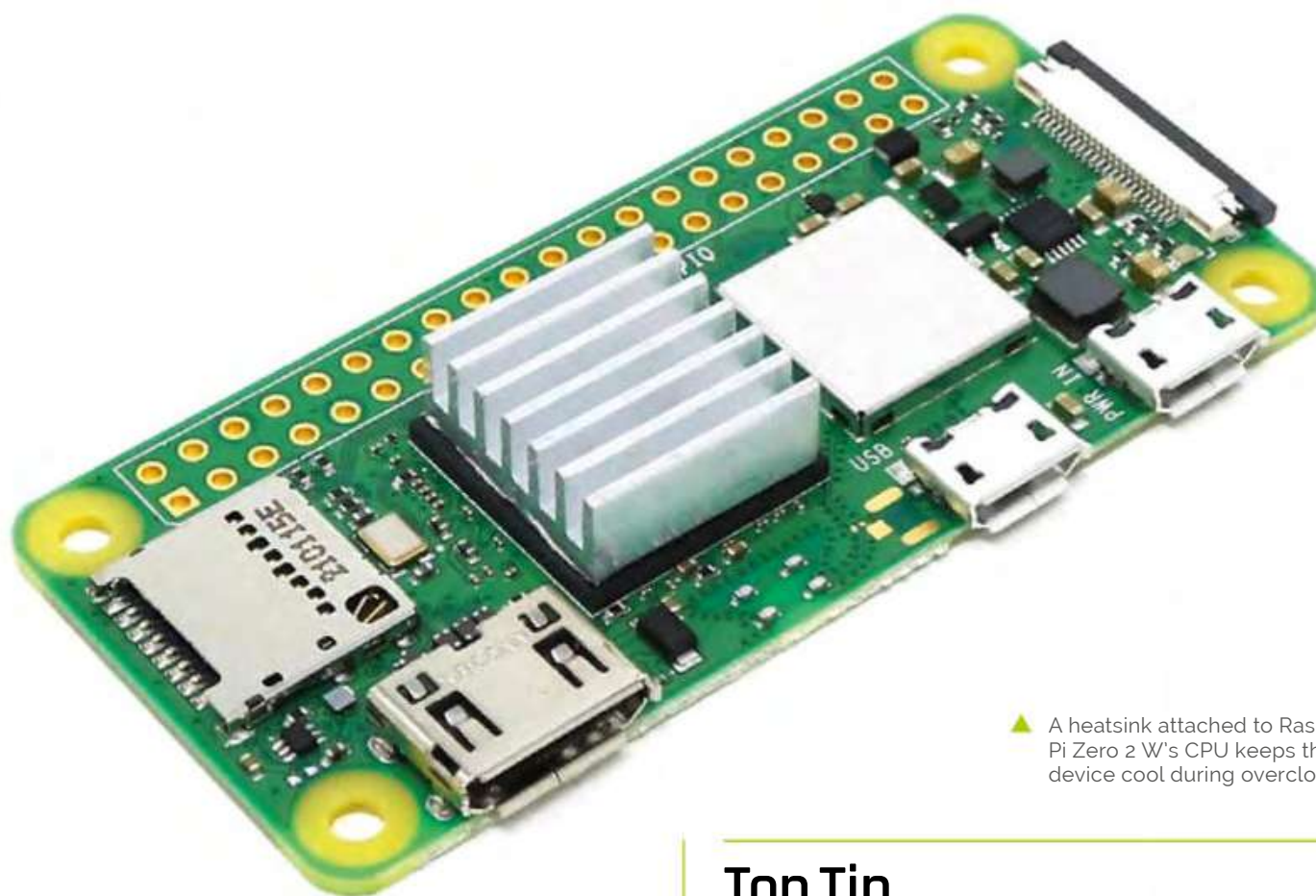
## Top Tip

### Monitoring voltage

It is essential to keep the supply voltage above 4.8V for reliable performance. Note that the voltage from some USB chargers/power supplies can fall as low as 4.2V. This is because they are usually designed to charge a 3.7 V LiPo battery, not to supply 5V to a computer.

To monitor Raspberry Pi's PSU voltage, you will need to use a multimeter to measure between the VCC (5V) and GND pins on the GPIO. More information on power requirements is available on the Raspberry Pi website: [magpi.cc/powersupply](https://magpi.cc/powersupply).





▲ A heatsink attached to Raspberry Pi Zero 2 W's CPU keeps the device cool during overclocking



### Warning! Crash likely!

Experimenting with overclocking may crash your Raspberry Pi. There is a chance of corrupting the microSD card. Experiment with a clean Raspberry Pi OS installation and ensure no important data is at risk.  
[magpi.cc/overclock](http://magpi.cc/overclock)

## 06 Crank it up

Let's try taking things a little faster. Set the ARM CPU to 1.4GHz. We managed to get our Zero 2 W to run at this speed, but only by including the `over_voltage` setting. Edit the `config.txt` file:

```
over_voltage=6
arm_freq=1400
# gpu_freq=700
```

This is as high as we're going to take `over_voltage`. Reboot the Raspberry Pi and you'll be running at 1.4GHz. Run `watch -n 1 vcgencmd measure_clock arm` again to see the new upper limit. You can also try uncommenting the `gpu_freq`. The `gpu_freq` oversees a range of settings: `core_freq`, `h264_freq`, `isp_freq`, and `v3d_freq`. All the Zero 2 Ws we tested failed to boot with faster `gpu_freq` settings.

## config.txt

► Language: **Bash**

```
001. # Overclock settings
002. over_voltage=6
003. arm_freq=1400
004. #gpu_freq=700
```

## Top Tip



### Overclocking problems

Most overclocking issues show up immediately with a failure to boot. If this occurs, hold down the **SHIFT** key during the next boot. This will temporarily disable all overclocking, allowing you to boot successfully and then edit your settings.

Alternatively, remove the microSD card from your Raspberry Pi and insert it into another computer. You will be able to access the `config.txt` file and adjust the settings from there. If all else fails, use Raspberry Pi Imager to install a fresh copy of Raspberry Pi OS to the microSD card.

“ The `gpu_freq` setting should be removed if a Raspberry Pi fails to boot ”

## 07 Recover from black screen

We think `arm_freq=1200` is a good speed boost. Our engineering team told us that the benefits from `gpu_freq` are marginal at best, and the `gpu_freq` setting should be removed if a Raspberry Pi fails to boot. Your Raspberry Pi is likely to fail to boot at some point during overclocking. See ‘Overclocking problems’ (above) for more information on recovery. Otherwise, have fun and enjoy squeezing the most out of your Raspberry Pi Zero 2 W computer. 🎮



# HDMI TFT Displays

Midas first introduced the HDMI TFT range in 2018, and have continued to develop this range over the past 3 years. These displays are ideal 'plug & play' devices for a Raspberry Pi SBC.



With the addition of a Raspberry Pi SBC, the Midas Displays HDMI TFT modules become a fully functional, easy-to-use displays. The integrated PCB has a 40-pin GPIO interface and a standard 19-pin type-A HDMI connector, enabling direct connection of a Raspberry Pi SBC. The HDMI TFT modules can also easily be used with many other single board computers. These key features enable the HDMI TFT displays to be used with any external HDMI input source.



## Key Features

- 4.3", 5.0", 7.0", 10.1", & 5.2" bar-type, sizes available
- IPS all-round viewing options
- 'Plug & play' with Raspberry Pi
- HDMI interface
- Capacitive, resistive, and non, touch options available
- Up to 1100cd/m<sup>2</sup> brightness

The products within the Midas HDMI TFT range are available to order direct, and through our distribution partners: Farnell, RS Components, and Digi-Key Electronics.

[www.midasdisplays.com](http://www.midasdisplays.com)  
+44 (0)1493 602602  
[sales@midasdisplays.com](mailto:sales@midasdisplays.com)



# Ultimate home server: Backup and UPS



PJ Evans

PJ is a writer, software developer and tinkerer. He keeps several clones of himself in storage just in case.

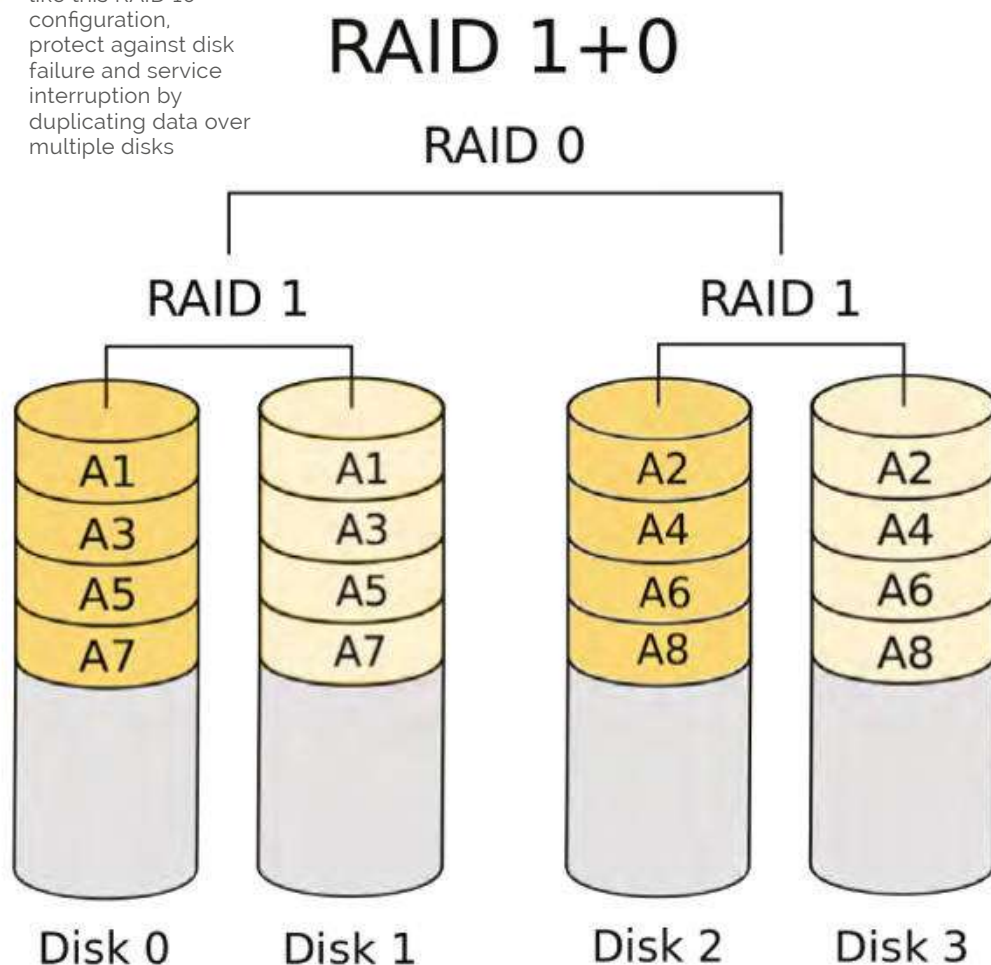
[twitter.com/mrpjevans](https://twitter.com/mrpjevans)

Now you have the ultimate server, let's keep your data safe with an uninterruptable power supply

**If you've been following our home server tutorials over the past months, you should now have a pretty sweet Raspberry Pi-powered server up and running, with file sharing, media streaming, remote access, and more.** In this final part of our Ultimate Server tutorial, we're going to look at protecting both your hard work and all that data you have entrusted to our favourite little computer.

We're going to cover the three key pillars of server management: Backup, Reliability, and Monitoring. Luckily, these are not hard to achieve, even for a home setup, and you never know: there may come a day when you're really glad you took the time to protect your investment.

RAID systems, like this RAID 10 configuration, protect against disk failure and service interruption by duplicating data over multiple disks



## 01 Don't be that person

When you've completed a project like this, it's tempting to stop now and enjoy the fruits of your labour. Sadly, the annals of computer history are filled with stories of those who did not heed the warnings and didn't back up. It's caused heartbreak when families have lost their photo libraries and bankruptcy when companies have lost their precious customer data. Never trust your data to one single source, no matter how much you've spent, or the reputation of the supplier. Think carefully about how to keep your data safe, not only from hardware or software failure, but also theft and disaster.

## 02 Three is the magic number

There's a long-held mantra amongst system administrators known as the 3-2-1 rule. You need three copies of your data, on at least two different media types with one off-site. Only then does your data safely 'exist'. This principle protects you against hardware failure and physical problems such as fire. Although this sounds initially complicated or at least a faff to set up, don't worry. Modern tools have made this easier than ever before. We can get your data to a healthy backed-up state without too





A simple way to keep data safe is to have a second copy ready to go

You can theoretically add up to 256 disk drives, but don't forget a powered USB hub even with just two, or you risk data loss

## “ You need three copies of your data, on at least two different media types ”

much work. What needs to be done is twofold: make sure the data is available elsewhere and that if you delete a file, you can get it back.

### 03 A local drive for local data

Let's start with a very simple way of backing up your data. We connected a 4TB drive to our ultimate server for all our lovely files. The easiest thing to do is to double it so we can mirror that data. Adding a second 4TB drive may sound expensive for little benefit, but when your original drive fails or you delete a critical file by

accident, you'll be holding a parade through the streets when you realise you've got that data safe and sound on the second drive. All you need to do is set up a regular backup routine to copy the contents of your first drive to the second.

### 04 Quick and easy backup

Assuming you're adding an identical USB drive to your server, make sure you've partitioned and formatted the drive identically to the original. See tutorial part 1 in *The MagPi* #107 ([magpi.cc/107](http://magpi.cc/107)) for details on how to do this. Next, do an initial backup to ensure everything is OK. This may take some time, depending on how much data you have. If your first disk is mounted to **/mnt/huge** and your new disk is **/mnt/backup**, the command would be:

```
sudo rsync -av /mnt/huge /mnt/backup
```

### You'll Need

- ▶ Raspberry Pi Ultimate Server (*The MagPi* issue #107 to #110) [magpi.cc/issues](http://magpi.cc/issues)
- ▶ Uninterruptible power supply (optional)
- ▶ Additional USB 3.0 external hard disks (optional)



There are many uninterruptible power supply (UPS) models available that provide a small footprint and adequate time for a clean shutdown, perfect for home use

## Top Tip

### Time Machine

Not only can you back up your ultimate server, but it can back up your Mac as well. Make your file shares Time Machine-compatible by following these instructions: [magpi.cc/timemachinegit](https://magpi.cc/timemachinegit)

Home Assistant can monitor your server and your UPS, triggering alerts when necessary



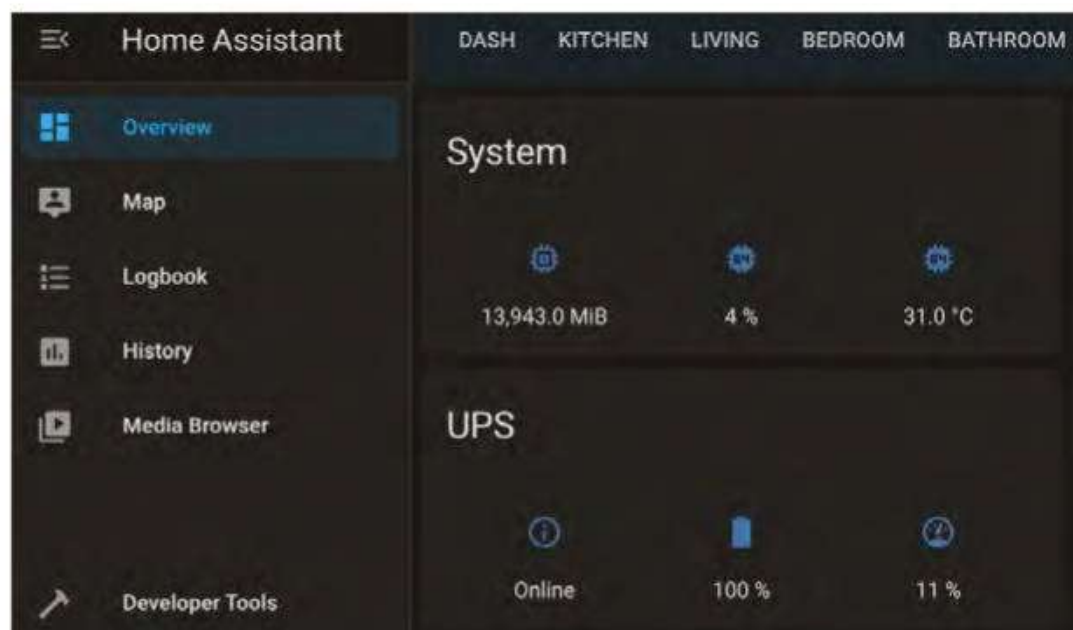
Rsync will only copy changes, so it's faster after the initial backup. To run this on a regular basis, add it to crontab (a schedule of regular jobs):

```
sudo nano /etc/crontab
```

Add this line at the end:

```
1 12 * * * root rsync -av /mnt/huge /mnt/
backup > /var/log/backup.txt 2>&1
```

This will run the backup every night at one minute past twelve. You can change it to any time or to be as (in)frequent as you like.



## 05 Let's go offsite

A central principle of a good backup policy is that at least one copy is nowhere near you. This is to protect against all those things we really don't want to think about such as fire, flood, theft, or other types of damage. A wide range of services exist to securely store your data for you for a reasonable fee. If the worst happens, a copy of all your precious data will be available to retrieve. Some even offer a hard-drive-by-post service. There are too many services to cover here, but some tried and tested solutions for Raspberry Pi OS include iDrive, Amazon S3, and BackBlaze B2.

## 06 Introducing iDrive

If you want to keep things easy, we can recommend iDrive ([idrive.com](https://idrive.com)) as a contender. Not only do they offer very attractive first-year terms: they are one of the few off-site backup companies to offer full Linux (i.e. Raspberry Pi OS) support. Although you'll need to do some navigation of the command line, you can install the iDrive tools and create a destination and a backup-set in a surprisingly short amount of time. If you have a lot of data, the first backup may take some time, but iDrive can throttle the bandwidth used. Once uploaded, a regular incremental backup keeps you up to date. Best of all, deleted files and different versions of files can be archived.

## 07 The amazing rclone

There are many services available that offer some form of 'block' or 'bucket' storage. Most popular is Amazon S3, but there are a growing number of contenders such as BackBlaze B2, Box, or Digital Ocean Spaces. Working out how to communicate with all these can be a challenge, but luckily rClone ([rclone.org](https://rclone.org)) knows how to talk to over 40 different services. Sign up for the service you want, get your credentials, and configure rClone using its menus. Although trickier to configure than iDrive, this can be a very cheap way of backing up in the long term.

## 08 Let's get physical

In the modern age of the cloud, this may seem like an unnecessary step, but hear us out. How far you go with backup is dependent on how



valuable you perceive your data to be. Typically, photographs fall into this category: memories that are irreplaceable. This is where the ‘two types of media’ rule can come into play. If you absolutely need that extra peace of mind, consider either burning the data to good-quality DVD or Blu-ray ROMs or, as many photographers do, never reusing an SD card and archiving them as you go. Many banks offer a cheap safety-box service where you can store physical media.

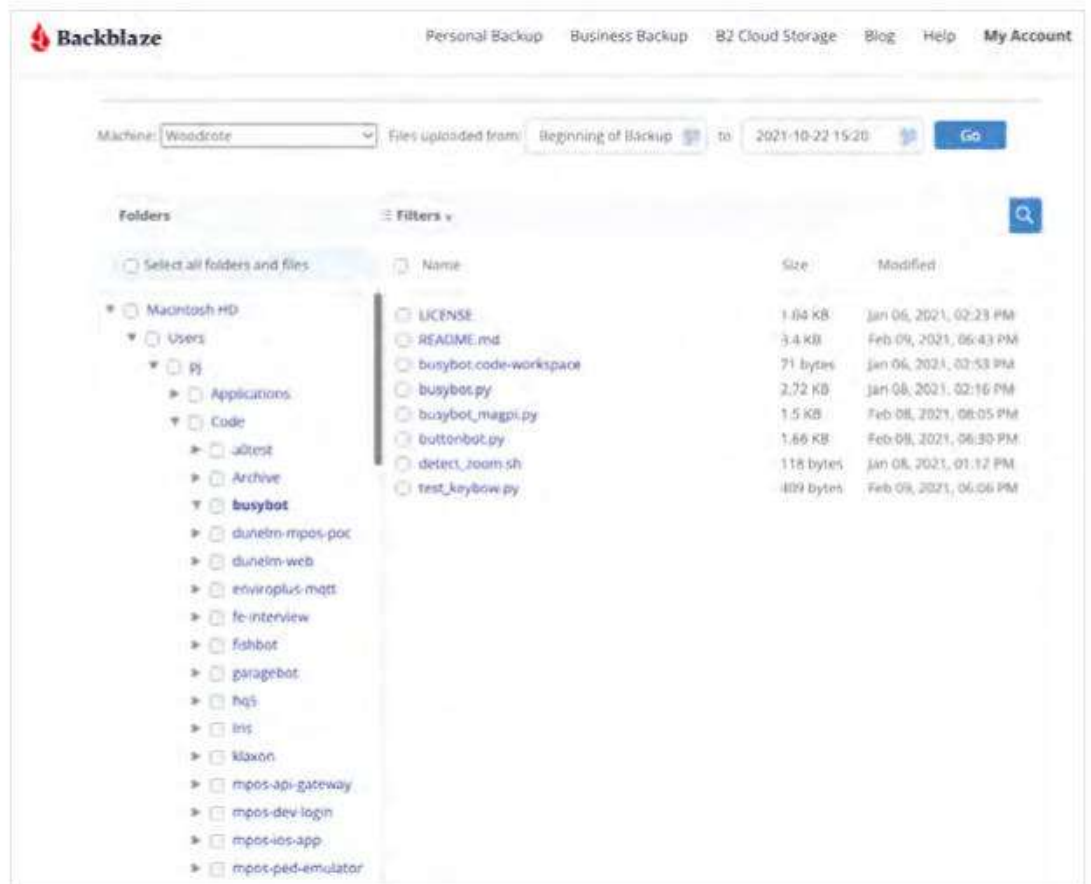
“ As for off-site data storage, there really are no practical limits ”

## 09 Please don't interrupt

Now backups are sorted, let's look at making sure you don't need them. One of the classic causes of data loss is a sudden power cut. This is due to the operating system constantly writing and reading its storage and sometimes caching reads and writes in memory (known as ‘journaling’). An inopportune power cut can use file system corruption and the loss of data. An uninterruptible power supply (UPS) is a battery that can keep your server going during a power cut. In the case of a Raspberry Pi computer, sometimes for hours. Best of all, they can communicate with your server over USB and invoke a safe shutdown when the battery gets low, protecting your data. Good UPSs for home use start at around £80.

## 10 Redundancy is a good thing

Another aspect of good server management is availability. If you have all your cool data on the server, you want to make sure it can handle failure and keep going. Although the two-drive system will prevent data loss, it's going to be a pain to reconfigure everything. For a truly robust system, you need a redundant array of inexpensive disks (RAID). This is a file system that allows a number of disks to operate as one and can tolerate at least one drive failure. You can then replace the drive and have the data protected again with no downtime at all. The ZFS file system is especially good at this.



## 11 Two heads are better than one

Server reliability can often turn into a rabbit hole: when do you stop? The principles of high availability (HA) will keep a server running no matter what. If you really need to keep things ticking along, you need to eradicate every single point of failure, and that includes the server itself. In the last step, we removed a single hard drive as a point of failure. Using the principle of load balancing, we can remove the server as well. Software such as Varnish can split the load between two or more Raspberry Pi servers and if one fails, everything keeps on working. Magic!

▲ Companies like BackBlaze and iDrive offer cheap off-site backup services so you know your data is safe

## 12 Let it grow

Nothing we have discussed here prevents your server from growing in the future. Modern RAID systems such as Z2 allow you to increase disk capacity with no downtime. Using load-balancing software such as Varnish means you can add in more servers, or replace failed hardware, without anyone noticing. You're free to add more software and features whenever you want. As for off-site data storage, there really are no practical limits. Any time you need to boost your hardware, it's possible to do it with no interruption, again and again, truly making it the ultimate server. 🧙

## Top Tip

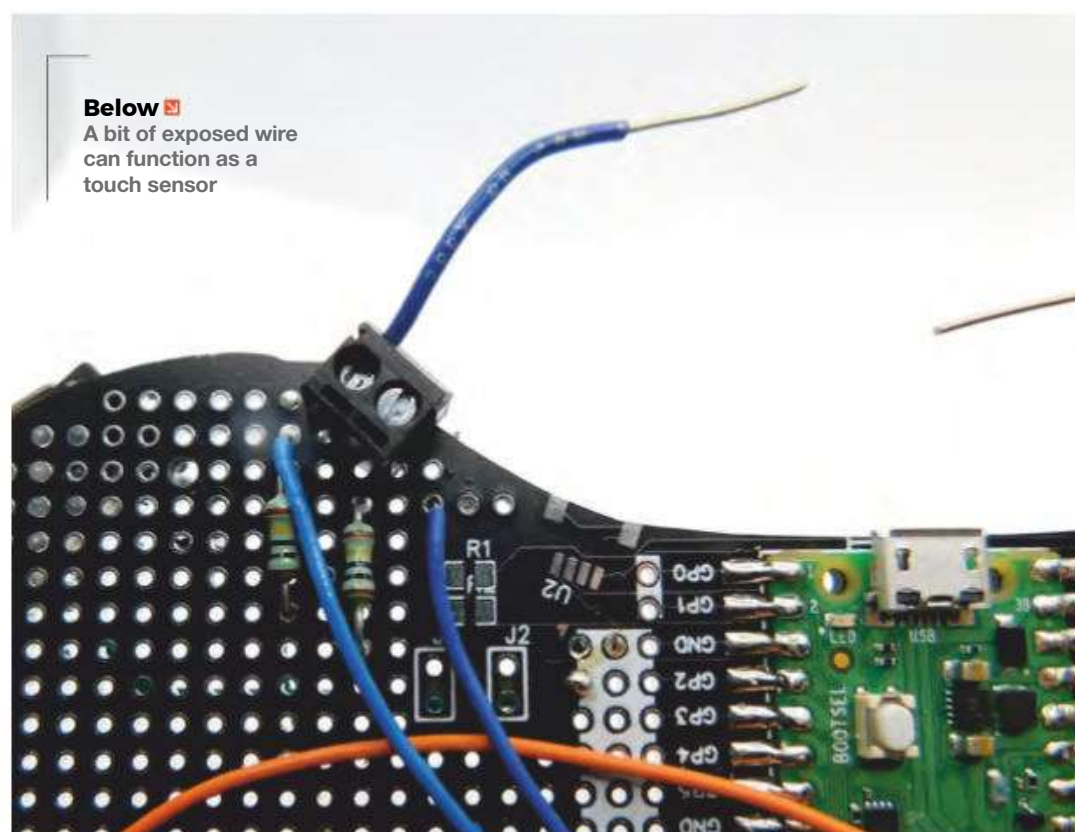
### Remote Monitoring

If you want to monitor your server from afar and have exposed a web server to the internet, services such as **uptimerobot.com** will alert you if they can no longer reach your site.



# Touch inputs with Raspberry Pi Pico

Poke data into Pico – no buttons needed



Ben Everard

@ben\_everard

Ben's house is slowly being taken over by 3D printers. He plans to solve this by printing an extension, once he gets enough printers.

**R**aspberry Pi Pico doesn't have capacitive touch hardware on board. However, that doesn't mean we can't use capacitive touch. To understand how, we first need to learn a little about how capacitive touch works.

All electrical conductors have some amount of capacitance – basically, this is an ability to store electrical charge. If you put one end of a wire into a circuit without the other end attached, you might think that no electricity flows, but actually, a little does. It charges the wire and this small charge will remain stored in the wire until it's discharged. How much charge it stores depends on the size of the wire, what it's made from, etc.

Capacitive touch sensing works because your body is a conductor. If you connect a wire to a circuit that you're holding the end of, it'll be able to store slightly

more electrical charge than it would if you weren't holding the end of it. The question is, how do you read the value of this charge?

The easiest way is to discharge it and see how long it takes to discharge. For this, we need a way of discharging the touchpad – basically, a resistor connected to ground. As the amount of capacitance in the wire plus a person is very low, we want a very large resistor to slow down the discharge to a speed we can measure. We use a 1 MΩ resistor for this.

**The pseudo-code to tell if a pad is currently touched is:**

- Set pad to output and drive it high
- Turn pad to an input
- Continue to read pad state until the pad goes low
- Return the amount of time this took

The higher the capacitance of whatever is attached to the pad, the longer this will take (though it should only be a tiny fraction of a second). If it's above a certain threshold, then we consider the pad touched. If not, then we don't.

The good news is that CircuitPython can do all of this for us. All we need to do is attach the external 1 MΩ resistor between a pad and ground.

We can then read the state of the touch sensor with:

```
import time
import board
import touchio

touch_pad = board.GP9

touch = touchio.TouchIn(touch_pad)

while True:
    if touch.value:
```



```
print("Touched!")
time.sleep(0.05)
```

The `touchio` module is built into CircuitPython, so you don't need to add it. It should work on all boards, though on some, you won't need the external pull-down, and on others, it will only work on some pins; so if you have trouble, look at the documentation for your board. On Pico, you can use it on any pin as long as you add the resistor. We've used GP9, but change this to something different if that works for you.

## MAKING A GAME

Let's make a simple reaction game. In this, we'll light up an LED, then the aim is to touch the touchpad as soon as possible after the LED lights up.

This is done with the following code:

```
import time
import board
import touchio
import digitalio
import random

touch_pad = board.GP9
led_pin = board.GP25
led = digitalio.DigitalInOut(led_pin)
led.direction = digitalio.Direction.OUTPUT

touch = touchio.TouchIn(touch_pad)
led.value = False

time.sleep(random.randint(5,10))
led.value=True

start = time.monotonic()

while not touch.value:
    pass

score = time.monotonic() - start
print(score)
```

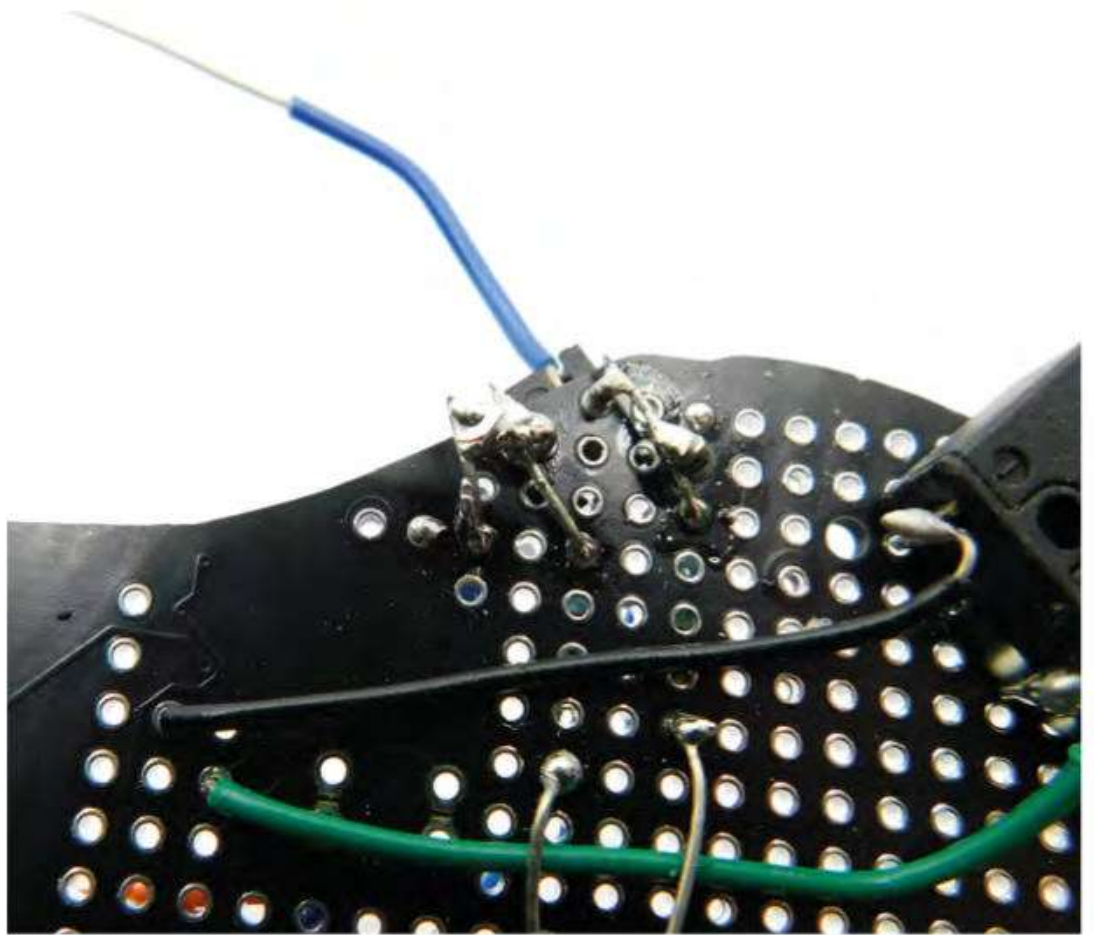
We're using the internal LED on Pico, so there's no need to add extra hardware.

We use the following line to pause the execution for a random amount between five and ten seconds:

```
time.sleep(random.randint(5,10))
```

There's then a `while` loop that does nothing but pause until `touch.value` becomes true.

This code is a bit simplistic because it just finishes at the end of the game. You could get it to loop around again if you wanted to make a game that played over and over.



## THRESHOLDS

We mentioned at the start that this is just reading the capacitance of the pad and whatever it's connected to. However, how does CircuitPython know if a capacitance is enough to be a touch? After all, if you're attaching different hardware to Pico, you might get different capacitances.

It's done with a simple thresholding. You can see the actual value returned by the touch sensing with:


```
import time
import board
import touchio

touch_pad = board.GP9

touch = touchio.TouchIn(touch_pad)

while True:
    print(touch.raw_value)
    time.sleep(0.05)
```

When you first create a touch input, CircuitPython checks the raw value and sets the threshold to that value plus 100. However, in some cases, that might be too sensitive or not sensitive enough. You can manually adjust the threshold with the `touch.threshold(value)` function.

That's all you need to know to start creating your own touch-sensitive projects. A touch sensor can be absolutely anything that's conductive. It can be a bare wire, a pad on a PCB, or something made out of tinfoil. You can be as artistic as you like. 

**Above**  The touch inputs on this games controller are a bit messy, but they work well



## HackSpace

This tutorial is from HackSpace magazine. Each issue includes a huge variety of maker projects inside and outside of the sphere of Raspberry Pi, and also has amazing tutorials. Find out more at [hsmag.cc](http://hsmag.cc).





## WIZnet Ethernet HAT for Raspberry Pi Pico

**\$ 4.95**

- Raspberry Pi Pico H/W pin compatible
- W5100S integrates hardwired TCP/IP stack with 10/100 Ethernet MAC and PHY
- Supports hardwired internet protocols : TCP, UDP, WOL over UDP, ICMP, IGMPv1/v2, IPv4, ARP, PPPoE



- MCU : RP2040
- Ethernet connectivity IC : W5100S
- Micro-USB B port for power and data
- 23 GPIO are digital-only and 3 ADC capable
- 3-pin ARM Serial Wire Debug(SWD) port

## W5100S-EVB-Pico on Raspberry Pi RP2040

**\$ 9.95**



## Upcoming Design Contest from December to February 2022

Sum of prize for H/W & S/W  
winners will be **\$30K**

More details at QR (<https://maker.wiznet.io>)





# Make *your own gifts with* Raspberry Pi

Build the ultimate personal gift for your loved ones

**O**ne of the goals of the magazine is to inspire people to build things using Raspberry Pi. There's so much you can do with the various Raspberry Pi computers and Raspberry Pi Pico, and we hope that just one idea lights a spark.

Lots of people get a new Raspberry Pi for Christmas, but what if they got some inspiration too? Building something unique and amazing might just be the way to get someone interested, and it makes for an incredibly personal gift as well – especially if they can start using it day-to-day.

So, grab some wrapping paper in one hand and awkwardly balance a 3D printer in the other, and let's get festive.





# Raspberry Pi gift guide

Kits for those who might  
prefer to build it themselves

## Grow Kit with herb pack

URL: [magpi.cc/growkitherbs](http://magpi.cc/growkitherbs)

PRICE: £40 / \$45

Grow some basil in style with this plant  
monitoring system

## Picade

URL: [magpi.cc/picade](http://magpi.cc/picade)

PRICE: £165 / \$225

Build-it-yourself mini arcade

## Pirate Radio

URL: [magpi.cc/pirateradio](http://magpi.cc/pirateradio)

PRICE: £48 / \$54

A smart-looking Raspberry Pi Zero  
internet radio kit

## RockyBorg

URL: [magpi.cc/rockyborg](http://magpi.cc/rockyborg)

PRICE: £99 / \$135

Three-wheeled fun with this  
budget, but excellent, robot kit







## MonsterBorg

URL: [magpi.cc/monsterborg](http://magpi.cc/monsterborg)  
PRICE: £210 / \$286

Serious robotics for serious racing



## PiBoy DMG

URL: [magpi.cc/piboydmg](http://magpi.cc/piboydmg)  
PRICE: £96 / \$130

Create the ultimate handheld retro gaming machine

## AIY Vision Kit

URL: [magpi.cc/aiyvision](http://magpi.cc/aiyvision)  
PRICE: £83 / \$93

Machine learning with a camera for image recognition



## 13.3" magic mirror

URL: [magpi.cc/magicmirrorkit](http://magpi.cc/magicmirrorkit)  
PRICE: £185 / \$208

Make your own smart mirror quicker





# Smaller gifts on a budget

Recycle a Raspberry Pi  
with these simpler projects



## Media centre

**URL:** [magpi.cc/102](https://magpi.cc/102)

**MAKER:** Rob Zwetsloot

**COST:** £10 / \$10 minimum, and a spare Raspberry Pi

Media centres are mostly software-based, and the simplest ones only require a Raspberry Pi and a case to put them in. The guide we wrote in issue 102 allows you to play retro games, watch movies and TV, and stream shows all in one little box. The cost of parts for that build is around £50 / \$60; however, you don't need everything we used, so pick and choose as your budget allows.

For an extra-special treat, make sure it has the info for the recipient's WiFi network so they can get using it straight away.

## Retro games box

**URL:** [retropie.org.uk](https://retropie.org.uk)

**MAKER:** RetroPie

**COST:** £20 / \$20 and a spare Raspberry Pi

Setting up a RetroPie box is incredibly easy, and we cover the process in our Ultimate Media Centre feature in *The MagPi* issue 102 ([magpi.cc/102](https://magpi.cc/102)). All you need for your spare Raspberry Pi is a case and a controller or two. A Raspberry Pi 4 would be best, but you can still make an excellent retro gaming machine with a Raspberry Pi 3 or newer.

You can also preload it with new games that are made to be run as ROMs on emulators – find out about them on [magpi.cc/legalroms](https://magpi.cc/legalroms).





❶ This cost of a digital frame like this depends a lot on the size of the display ❷

## Digital photo frame

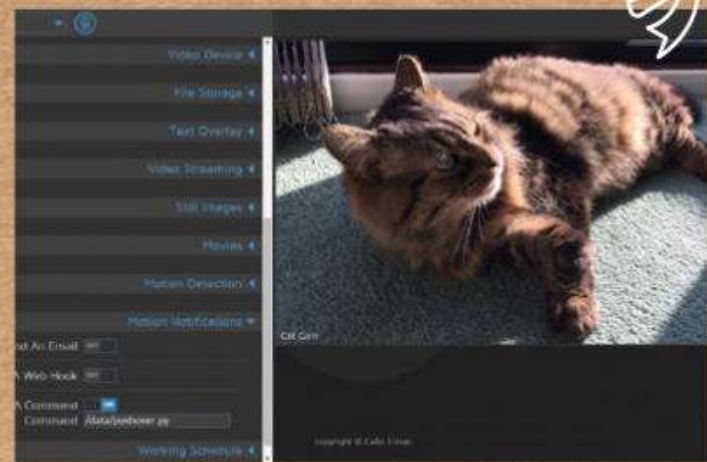
URL: [magpi.cc/photoframe](http://magpi.cc/photoframe)

MAKER: **Caroline Dunn**

COST: £30-£70 / \$40-\$95, and a spare Raspberry Pi

This cost of a digital frame like this depends a lot on the size of the display you plan to use, if you're not reusing an old one, as well as whether you plan to frame it with wood or a 3D-printed case. Once again, it's very software-orientated, and loading it with pictures the recipient will like (along with a way to change them) should go down well.

You can always switch out the use of Google Photos for LibreELEC and store the photos offline as well.



## Security camera

URL: [magpi.cc/camerabook](http://magpi.cc/camerabook)

MAKER: **Phil King**

COST: £34 / \$40 and a spare Raspberry Pi

Whether you have a security-conscious friend, or someone that likes to watch their garden wildlife, Raspberry Pi can work great as a security camera. We have a great tutorial in chapter 16 of the official *Raspberry Pi Camera Guide* ([magpi.cc/camerabook](http://magpi.cc/camerabook)) using the powerful and free motionEyeOS. There's also a specific wildlife nature camera tutorial in there as well if you fancy doing something a bit more advanced.

The price here takes into account a regular Camera Module. However, if you have the budget, it can easily be upgraded to a HQ Camera.

## TOP MAGPI WRAPPING TIPS: easy to open

Washi tape is a kind of sticky tape that has printed designs on it – it's also a little less adhesive than regular tape. Get some Christmas-themed tape and use it on your gifts to make them a bit easier to open, and much more festive.





# Cool projects to inspire

Go-to builds for tech lovers

## Handheld console

**URL:** [magpi.cc/55](https://magpi.cc/55)

**MAKER:** Ruiz Brothers

**COST:** £50 / \$60, plus 3D-printed materials

It doesn't seem that long ago that we made this Raspberry Pi Zero-powered handheld in the magazine – the whole thing still works great, though. It's based on a build from Adafruit called PiGRRRL 2.0 which used a full-size Raspberry Pi, and you could swap it out for a newer Raspberry Pi if you wish – although you may need to edit the STL files for the case if you use a Raspberry Pi 4.

Speaking of 3D printing the files, we recommend using a softer material for the buttons and D-pad. Your recipient's thumbs will thank you in the long run.



## RadioGlobe

**URL:** [magpi.cc/radioglobebuild](https://magpi.cc/radioglobebuild)

**MAKER:** Jude Pullen

**COST:** £230 / \$300 plus, 3D-printed materials

This is a very cool build that requires a decent toolbox and a bit of maker experience. Basically, you spin the globe and then move the reticule up and down, and the nearest radio station to wherever in the world the reticule is over will be played. Jude, the creator, mentions how he's discovered loads of great music using this. It uses web radio to play the feeds, and the physical build itself is made up of a variety of components to make the whole thing work. You can probably do it cheaper by selecting different parts, or recycling some stuff from your own home.





## Digital camera

**URL:** [magpi.cc/beccacam](http://magpi.cc/beccacam)

**MAKER:** Becca Farsace

**COST:** £110 / \$150 plus an old camera shell

We featured this in the magazine last year, where Becca used a classic camera shell to create her own, very nice, digital camera using a Raspberry Pi and a HQ Camera. It also has an LCD screen so you can get nice previews. It would also work well with a new Raspberry Pi Zero 2 W if you'd like to save space elsewhere.

Old and broken cameras can be found on eBay pretty cheaply, but otherwise you could 3D-print your own case for this build.



🕒 Old and broken cameras can be found on eBay pretty cheaply 🕒

## Weather station

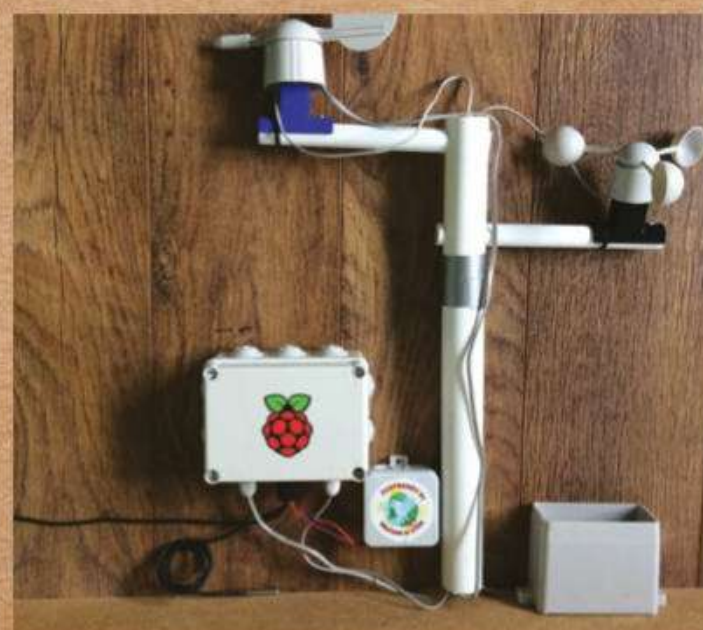
**URL:** [magpi.cc/weatherstation](http://magpi.cc/weatherstation)

**MAKER:** The Raspberry Pi Foundation

**COST:** Varies

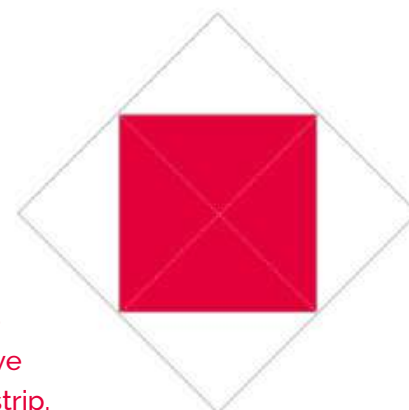
You can do something like this in two ways. You can either make a screen like a digital photo frame (see previous page) that displays weather data from the internet. Or, you can build a full-on weather station to know exactly what the weather is like right now.

This project is a little bit on the large side, and will need the recipient to mount parts of it outside, so make sure they can do something like this first! The original kit for the Oracle weather station is sold out now, but you can source parts using the Foundation's guide.



## TOP MAGPI WRAPPING TIPS: not enough paper

You've cut out a square of wrapping paper and it's just a bit too small for the gift? Try turning the paper 45 degrees – it's a more efficient use of paper, and may save you cutting off an awkward extra strip.





# Mega builds to impress

These ones won't fit under the tree



## Magic Mirror

URL: [magicmirror.builders](http://magicmirror.builders)

MAKER: **Michael Teeuw**

COST: £100-£200 / \$150-\$300

A classic build for many Raspberry Pi makers, Magic mirrors can be quite cheap if you have a spare TV lying around and some basic skills in carpentry. Otherwise, a cheap IKEA frame is how original maker Michael got his start with it.

Preload it with nice phrases for the intended recipient, and make sure they have space for something like this near a power socket. Soup it up with voice controls, as seen in *The MagPi* issue 90 ([magpi.cc/90](http://magpi.cc/90)).



## Arcade machine

URL: [magpi.cc/63](http://magpi.cc/63)

MAKER: **Bob Clagett**

COST: £250/\$350 or more

A dream gift for many people, this full arcade machine build from issue 63 includes decals, proper buttons, and light-up strips. It's a big build, so you may want to get started on it right now if you want to get finished in time.

Some updates we'd suggest are using the Picade X HAT ([magpi.cc/xhat](http://magpi.cc/xhat)) from Pimoroni, which helps a lot in connecting all your arcadey bits to a Raspberry Pi – it even includes left and right speaker connectors. We'll leave the wrapping ideas to you – we're not sure WH Smith sells gift bags this large.

🕒 Preload it with  
nice phrases for the  
intended recipient 🕒





## Robot sail boat

URL: [ubcsailbot.org](http://ubcsailbot.org)

MAKER: **University of British Columbia**

COST: A lot

Automated model sailing competitions are a thing people do, and we've featured a couple of these projects in the magazine in the past. One of our favourites is the UBC Sailbot. It's a 5.5 metre-long sailboat, complete with a Raspberry Pi controlling it. We don't have a price estimate because there's a lot of custom and expensive work going into its construction.

You'll need some serious building and nautical engineering skills to recreate this. However, you might just end up being someone's favourite relative or friend for a long time.



## Automated garden

URL: [magpi.cc/mudpi](http://magpi.cc/mudpi)

MAKER: **Eric Davisson**

COST: £150 / \$200 dependant on size

Automated gardening is very cool we think, and the MudPi system that we featured in the magazine a little while ago is a great way to start your own little robotic farm – and maybe grow it to something larger. It monitors soil and plant conditions, controls irrigation, and allows for remote access and reports so even if you're not there, your plants get cared for.

We suggest making a little box garden for a gift recipient that they can then plant in a garden, or put on a balcony. They can easily add extra modules if they start getting the hang of it.

## TOP MAGPI WRAPPING TIPS: easy bows

If you want to go extra fancy, use a ribbon on your gifts. The easiest way to attach the ribbon is to lay it across the top of the gift lengthways. Wrap around the box with both ends of the ribbon, and when they cross in the middle, twist them around each other 90 degrees clockwise. Wrap the rest up to the top and tie a bow for that classic wrapped look.



### Warning! Power Tools

These projects will involve the use of serious tools, so be careful if you plan to replicate them.



# Midas 5in TFT LCD

## SPECS

### DIMENSIONS AND ENVIRONMENT:

Module size:  
120.70 × 75.80  
× 23.20mm;  
Operating  
temperature:  
-20°C ~ +70°C;  
Logic voltage: 5V

### DISPLAY:

Display size: 5.0  
inch; Resolution:  
800×480;  
Orientation:  
Landscape;  
Brightness:  
750cd/m²

### INPUT/OUTPUT:

Touchscreen:  
CTP; Interface:  
HDMI; Pinout:  
40-pin GPIO

► Midas Displays ► [magpi.cc/farnellmidas](http://magpi.cc/farnellmidas) ► £77 / \$105

Turn Raspberry Pi into a professional touchscreen display system. By **Lucy Hattersley**

**D**isplays like this Midas 5in TFT LCD are used in a variety of industrial settings. Don't be surprised if you've already used one of these in a vending machine, EV charger, or information display.

Midas sent us a 5in IPS display for testing (part number: MDT0500D2IHC-HDMI, [magpi.cc/midas5in](http://magpi.cc/midas5in)). It is a small screen with a quirky 800×480 resolution and 5:3 aspect ratio. It also comes with a ten-point capacitive touchscreen and GPIO integration.

The screen is connected to the Raspberry Pi via the GPIO pins. A look at the datasheet ([magpi.cc/midas5indatasheet](http://magpi.cc/midas5indatasheet)) shows that GPIO17 is used to control the backlight, and power is passed through the GPIO pins (it is powered via a standard 5V supply connected to Raspberry Pi). A GPIO breakout on the rear of the device enables you to attach further electronic components or HATs.

The Midas 5in TFT LCD has the same resolution as the Official Raspberry Pi 7in Touchscreen Display ([magpi.cc/officialdisplay](http://magpi.cc/officialdisplay)). However, this device uses an HDMI connection for the display, and a micro-USB to USB-A cable to provide touchscreen feedback.

Our test unit came with a U-shaped MCIB-HDMI adapter that neatly connected Raspberry Pi 3B+ to the display. We tested it with a Raspberry Pi 4 using a Mini-HDMI to HDMI cable and it worked just fine.

## Setting up

Our test unit came with a Raspberry Pi 3B+ and microSD card, along with some printed instructions. It was easy to disassemble and, consequently, reassemble. Just attach it to the GPIO pins, insert the HDMI and USB cables, and away you go.

▼ Here we are using MagicMirror<sup>2</sup> to build a custom information board



## config.txt

► Language: **Bash**

```
001. ### Select Custom Timings
002. hdmi_group=2
003. hdmi_mode=87
004.
005. ## Disable audio over HDMI
006. hdmi_drive=1
007.
008. # HDMI Timings for MCT050HDMI-A series
    (800x480)
009. hdmi_cvt=800 480 60 6 0 0 0
```





◀ The 800×480 display needs configuring to show the desktop in Raspberry Pi OS

▶ Raspberry Pi connects to the MDT0500D2IHC board via GPIO pins, a HDMI connection, and USB

The 800×480 resolution is non-standard, so getting the screen to work requires editing the **config.txt** file. It's nothing particularly hairy, but you will need to set custom timings. You can find the info you need on Raspberry Pi's Documentation site ([magpi.cc/custommode](http://magpi.cc/custommode)). The key part is the timings, which you'll need to set at: 'hdmi\_cvt=800 480 60 6 0 0 0'. We've included the **config.txt** additions in this review for reference.

### What you can do?

With everything working, we had a lot of fun turning our MDT0500D2IHC into a variety of different projects. We turned it into a magic mirror ([magpi.cc/magicmirror](http://magpi.cc/magicmirror)) and created a weather information board; we then used Info-Beamer ([magpi.cc/infobeamer](http://magpi.cc/infobeamer)) to turn it into a photo display board and play video clips. In addition, we added an on-screen keyboard to

“ The visual fidelity is superb and the touchscreen response is immediate ”

Raspberry Pi OS using both Florence and Matchbox ([magpi.cc/onscreenkeyboard](http://magpi.cc/onscreenkeyboard)).

On the whole, this is a great display. The visual fidelity is superb and the touchscreen response is immediate. The physical setup couldn't be any easier, and the configuration is easy once you have the correct timings info. While Midas provides a detailed datasheet ([magpi.cc/midas5indatasheet](http://magpi.cc/midas5indatasheet)), there is little tutorial support for beginners, presumably as a result of its industrial engineering background. But if you want a small screen to integrate into a build, or want to experiment with a small magic mirror or information screen; this is a great choice. 📺

## Verdict

A fantastic display with an excellent touchscreen and good Raspberry Pi integration. The configuration is easy enough once you have the correct timings. Midas could provide beginners with more documentation, though.

# 8/10



# PicoSystem

## SPECS

### INTERNALS:

RP2020 chip (dual Arm Cortex-M0+ running at up to 133MHz with 264kB of SRAM), 16MB of QSPI flash supporting XiP

### DISPLAY:

1.54" colour SPI IPS LCD (240×240 pixels)

### FEATURES:

D-pad and buttons, 525 mAh LiPo battery, piezo buzzer/speaker, CNC-milled aluminium case, wrist strap

► Pimoroni ► [magpi.cc/picosystem](https://magpi.cc/picosystem) ► £59 / \$66

A handheld console built around RP2040 and with game development in mind. **Rob Zwetsloot** boots it up.

**E**xtremely tiny handheld consoles have not always had the best track record in the microcomputer space. A few Raspberry Pi Zero efforts ended up being just a little too small and finicky for actual use, and it didn't quite help that they often used hard 3D-printed buttons that were uncomfortable. We're pleased to say that Pimoroni's PicoSystem, while still small, manages to avoid this.

It's made from milled aluminium, has proper buttons, and a nice little square screen with 240×240 pixels. It feels nice to hold – there's a bit of heft – and holding it is not uncomfortable. It comes with a game pre-installed: Super Square Bros, a platformer. However, the main draw really is that you can make games for it yourself.

### Make your own fun

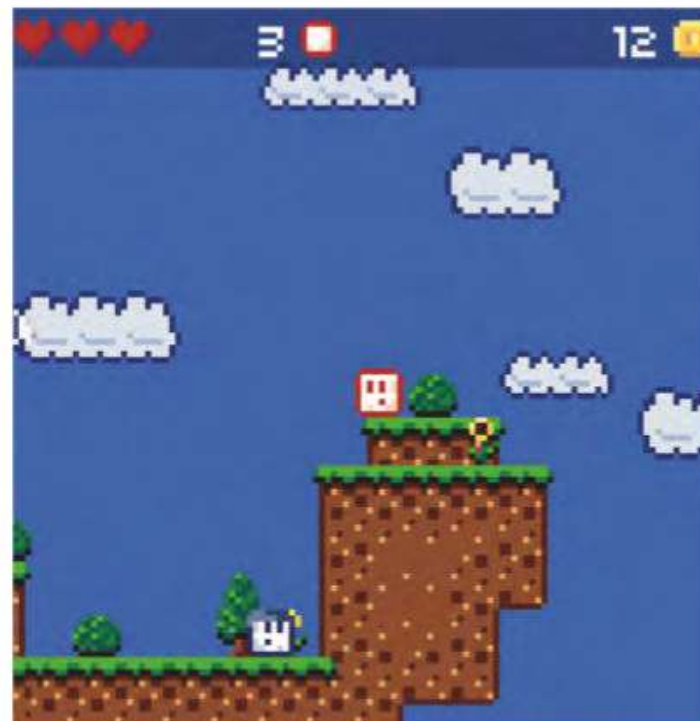
PicoSystem uses its own official API, which works MicroPython and C++ – just like a standard

Raspberry Pi Pico or other RP2040-based systems, allowing you to easily transfer skills over from elsewhere. CircuitPython, which is based on MicroPython is supported as well, and there's even a 32blit SDK, allowing you to port over games from Pimoroni's 32blit handheld console.

The standard C++ and MicroPython API adds loads of functions to make creating games slightly easier, including camera control, linking to buttons, and primitives for drawing sprites more easily than building them pixel by pixel. There are different in-engine effects you can apply to text and such – it's a meaty API that you can get a lot out of for just a simple pixel game on a limited piece of hardware.

The current games available for PicoSystem run absolutely fine as well, although the lack of a proper speaker is a little noticeable. The piezo buzzer sounds are quite charming in their own way, though, and smart use of it can create some nice retro bleeps and bloops.

► There are already some fun games that have been made for it








“ The main draw really is that you can make games for it yourself ”

### Pocket games

Switching out games is a little more tricky than changing cartridges, though – there’s limited space on the PicoSystem, and you need to connect it to a computer to do a quick re-flashing to play a different game. It’s not too frustrating, as it’s pretty quick, so for development you don’t have to wait too long. If you’re out and about with it hanging from your wrist, though (it comes with a cool lanyard), you will be fairly limited.

Yet that hasn’t really stopped us. It’s lovely to take around with you, the battery lasts for ages and charges pretty quickly, and you can make some really beautiful stuff for it. We look forward to see what kind of games people make for it. 



▲ The PicoSystem is beautifully designed and feels premium

◀ It has a charm loop holder bit which is extremely important

## Verdict

An incredibly cool, tiny handheld that you can fairly easily develop games for. We just wish it had more storage.

9/10



# UPS HAT For Raspberry Pi Zero WH

## SPECS

### FEATURES:

LiPo battery recharge chip, voltage boost chip, multiple battery protection circuits, I2C bus communication for monitoring

### BATTERY:

803040 LiPo battery, 1000 mAh, 3.7V

### CONNECTIVITY:

6 × pogo pins connect to underside of GPIO header

► The Pi Hut ► [magpi.cc/upszero](http://magpi.cc/upszero) ► From £21 / \$24

Essential battery backup power for your Raspberry Pi Zero. By **Phil King**

**W**hen you have a Raspberry Pi Zero running constantly for an important task, such as to log data from a sensor, there's nothing more frustrating than a mains power cut. To avoid this, a UPS (uninterruptible power supply) is an essential bit of kit.

This Waveshare UPS HAT is an interesting option, supplied with a 3.7V 1000mAh LiPo battery. Fitting onto a sticky strip on the board, the battery has a short cable that plugs into the board's mini JST socket.

“ You can monitor the battery level by installing a simple Python program ”

With the battery installed, the board connects to a Raspberry Pi WH in a novel way: six springy pogo pins connect to the solder on the underside of the GPIO header for power, ground, and I2C pins. This leaves the GPIO header free for connecting other HATs on top.

Note that the UPS HAT will also work with any Raspberry Pi Zero with a soldered header – so long as your soldering isn't too messy and has regular peaks to make good connections.

## Battery power

Once fitted to a Raspberry Pi Zero with I2C enabled, you can power the HAT via its micro USB socket, then flick its on-board switch to power up Raspberry Pi – or just leave it off to charge up the battery for a while.

If the mains power goes off, it'll instantly switch to battery power. A fully charged battery should provide power for up to seven hours, depending on the Raspberry Pi Zero's workload. Naturally, the addition of any connected devices will reduce that time.

You can monitor the battery level by installing a simple Python program. This shows the real-time load voltage, current (negative if battery power is being used), power, and percentage. While we've seen more sophisticated power management features, such as on the PiJuice, it's a handy tool. ”

## Verdict

With a LiPo battery included, it represents very good value for money if you need to keep your Raspberry Pi Zero running during a power outage.

8/10

▼ The battery sticks to the board and plugs into its mini JST socket



▼ Raspberry Pi Zero fits on top, connected via pogo pins and secured with supplied standoffs



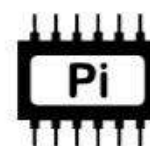


# DiP-Pi PICO

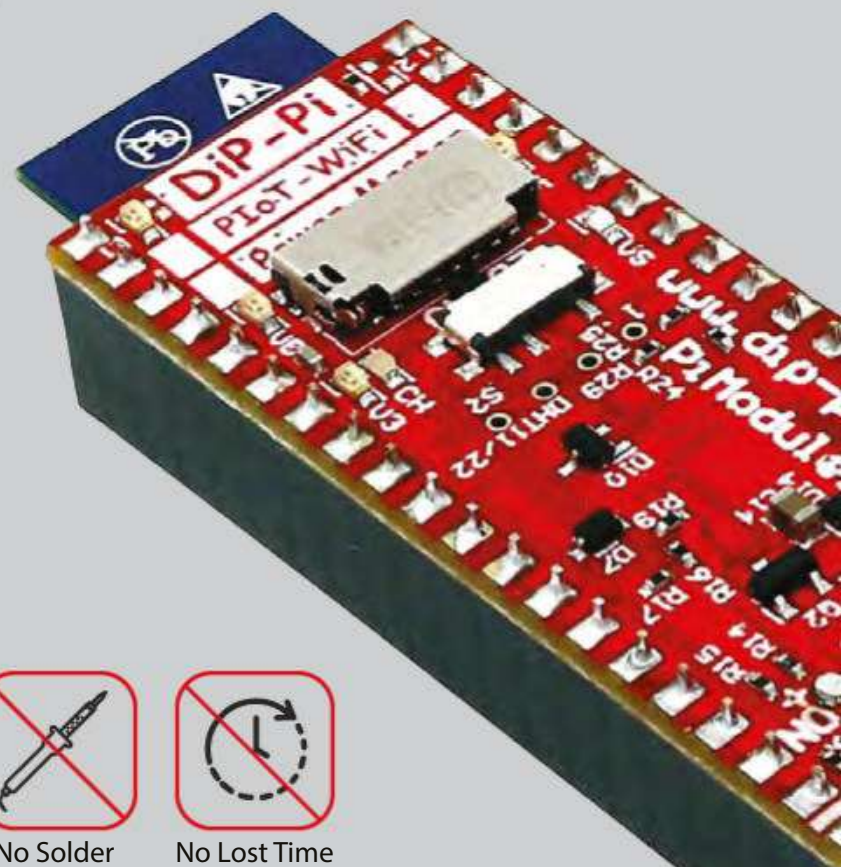
Dual In-Line Package Raspberry Pi Pico

Rapid Stackable Raspberry Pi Pico  
Add-on Boards

- Universal and dedicated metallic cases for professional as also amateur applications
- Plenty of ready-to-use examples written in MicroPython and C
- Just take it, load your software and the application is ready
- Open hardware (schematics)
- No need to do any soldering
- Extremely easy to use
- Ultra-low cost



dip-pi.com



No Cables



No Solder



No Lost Time

PloT



Power Master



Wi-Fi Master



## DiP-Pi PICO

### Key Feature

6-18V Power Input (EPR)  
Battery Power/Charging  
UPS Functionality  
On Board ON/OFF Switch  
On Board RESET Switch  
On Board ESP8266 Wi-Fi  
MicroSD Slot  
On Board 1-wire Interface  
On Board DHT22/21 Interface  
Plenty of Informative LEDs

### PloT

Yes  
Yes  
Yes  
Yes  
Yes  
Yes  
Yes  
Yes  
Yes  
Yes

### Power Master

Yes  
Yes  
Yes  
Yes  
Yes  
-  
-  
Yes  
Yes  
Yes

### Wi-Fi Master

-  
-  
-  
Yes  
Yes  
Yes  
Yes  
Yes  
Yes  
Yes

### DISTRIBUTORS:



Pi-Shop.ch

PiShop.us



semalelectronics

SOS SOLUTIONS



tiendatec



# 3.7" e-Paper e-Ink Display for Raspberry Pi Pico

## SPECS

### DISPLAY:

3.7-inch,  
480×280 pixels,  
four-level  
greyscale

### REFRESH:

3 seconds (full),  
0.3 seconds  
(partial)

### DIMENSIONS:

95.3×56.9 mm  
board,  
47.32×81.12 mm  
display area

► The Pi Hut ► [magpi.cc/epaperpico](https://magpi.cc/epaperpico) ► From £24 / \$28

Pico and e-ink should make the ideal low-power combination. By **Phil King**

**E**-ink displays have long proven useful for portable Raspberry Pi applications with low power requirements where the display doesn't require rapid updates. Combined with the lower-power usage and tiny footprint of Raspberry Pi Pico, an e-ink display makes an ideal combination for projects like a name badge or weather display.

This 3.7-inch Waveshare e-ink display features two female headers on the rear so that you can simply plug in a Pico (equipped with soldered male headers). The graphic on the board makes it clear which way round to orientate Pico to avoid getting the wrong connections.

The board also features an eight-pin SPI interface, so can be wired up to a Raspberry Pi computer, Arduino, or another microcontroller.

### Four shades of grey

While the 480×280 display is monochrome, it does offer four levels of greyscale for fairly accurate shading. One advantage of the greyscale display is that it takes less time to do a full refresh than on colour e-ink equivalents (which Waveshare also makes): just three seconds. Even better, it's possible to do a partial refresh of an area of the screen, for instance for updating a digital clock display, in a mere 0.3 seconds.

To make the e-ink display work, you'll need to visit the Waveshare wiki ([magpi.cc/epaperpicowiki](https://magpi.cc/epaperpicowiki)), and download a zip file containing C and Python example code and UF2 files to flash to Pico. The Python demo

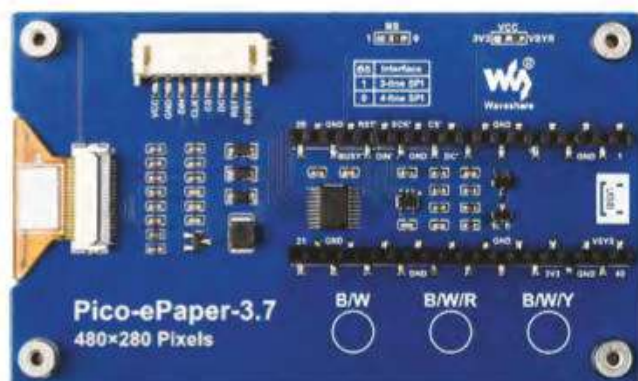


▲ As with all e-ink displays, anything on screen will remain there, even with no power

“ It does offer four levels of greyscale for fairly accurate shading ”

is limited and prints some text and a couple of rectangles in portrait mode. The C code – detailed in the wiki – uses landscape mode and is more extensive, printing text, drawing shapes, and showing a digital clock with seconds counting. There's no example of displaying a bitmap image, however, so you'll need to perform a bit of internet trawling to work out how to do it. 📺

▼ The rear features female headers to insert a Pico, plus an SPI interface to connect other boards



## Verdict

The display itself works well, and is fast to refresh, but you'll need to do some work on the code to make the most of it.

**7** / 10



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# 10 Amazing: Raspberry Pi LEGO projects

Using LEGO® with Raspberry Pi is easier than ever – here are some projects to start with!

**L**ast month we reported on the Raspberry Pi Build HAT, a new add-on that allows you to connect Raspberry Pi to LEGO systems for more precise control. People have been interfacing LEGO with Raspberry Pi for years, though, and here are some of the best so far... 

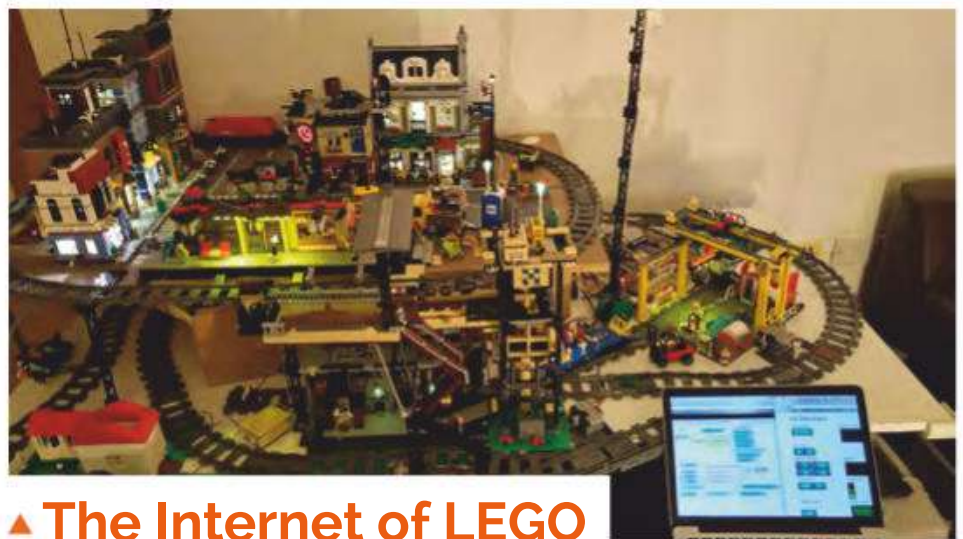


## ▲ Musicfig

### Toys-to-live

Combine RFID tags, LEGO Minifigs, and a LEGO Dimensions™ reader, and you can recreate your favourite bands who will 'perform' for you on the stage.

[musicfig.com](http://musicfig.com)



## ▲ The Internet of LEGO

### Automated LEGO city

This internet-connected cityscape has many functions controlled by Raspberry Pi, including a train, lights, and even a TfL train schedule.

[magpi.cc/internetoflego](http://magpi.cc/internetoflego)



## ▲ Hack LEGO Boost

### LEGO robotics

From issue 80 of *The MagPi*, we reprogrammed LEGO Boost using some Python programming in this three-part tutorial.

[magpi.cc/legoboost](http://magpi.cc/legoboost)

## ▶ BrickPi Bookreader 2

### Robotic literature

One of the original Raspberry Pi LEGO adapters, the folks at Dexter Industries made a little Mindstorms robot that scanned book pages automatically. Smart!

[magpi.cc/bookreader](http://magpi.cc/bookreader)







## ▲ LEGO robot face

### Expressive blocks

This amazing project from the Raspberry Pi Foundation uses a specific kit to build a robot face that is very animated and customisable.

[magpi.cc/robotface](http://magpi.cc/robotface)



## ▲ LEGO Raspberry Pi 3B+

### Blocky model

Using only pre-existing LEGO parts, you can make your own Raspberry Pi 3B+ – although it may not plug into your monitor so easily.

[magpi.cc/legopi](http://magpi.cc/legopi)

## ▼ LEGO Raspberry Pi Laptop

### Retro cool

Back in 2013, there wasn't really any kind of Raspberry Pi laptop or all-in-one Raspberry Pi computer system, so Peter Howkins built his own out of LEGO.

[magpi.cc/legopibook](http://magpi.cc/legopibook)

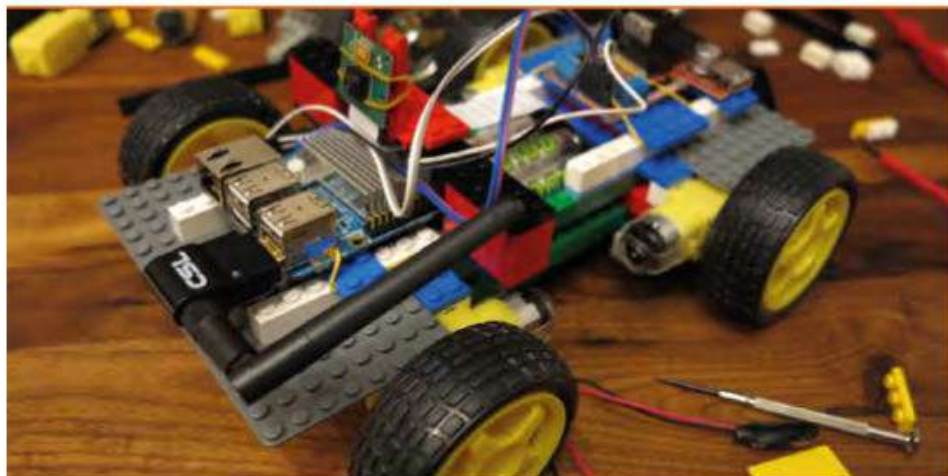


## ▼ Robot car

### Block chassis

This very DIY build is a great showcase of LEGO – a very modular car that you can change with your imagination.

[magpi.cc/robotcar](http://magpi.cc/robotcar)

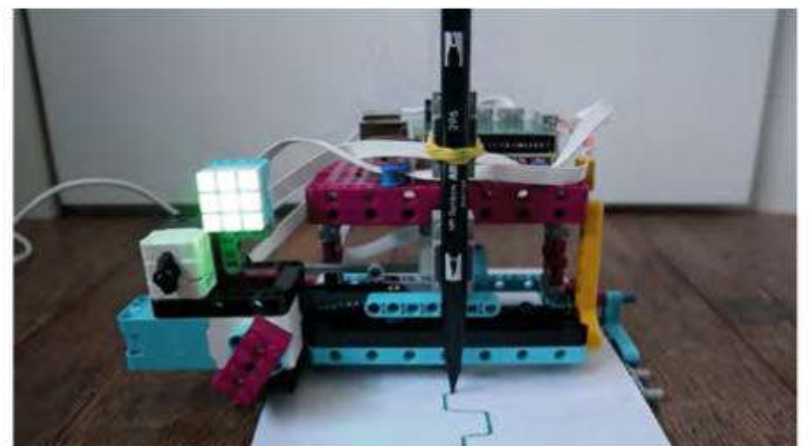


## ▲ LEGO NES Raspberry Pi case

### NES DIY

This used to be a kit, but it's a bit tricky to get hold of now – you can still build one yourself, though, if you collect the right standard LEGO parts.

[magpi.cc/legonespi](http://magpi.cc/legonespi)



## ▲ LEGO data plotter

### Polygraph or seismometer?

This cool-looking project portrays data as the line on a graph, for a great movie-like effect. It's actually able to use a variety of sensor inputs.

[magpi.cc/legoplotter](http://magpi.cc/legoplotter)



# Wireframe

Join us as we lift the lid  
on video games



Visit [wfmag.cc](http://wfmag.cc) to learn more



# Learn crafting and making with Raspberry Pi

Enhance your crafting and making skills with these resources. By **Phil King**

## Creativebug

**AUTHOR**


**Creativebug**

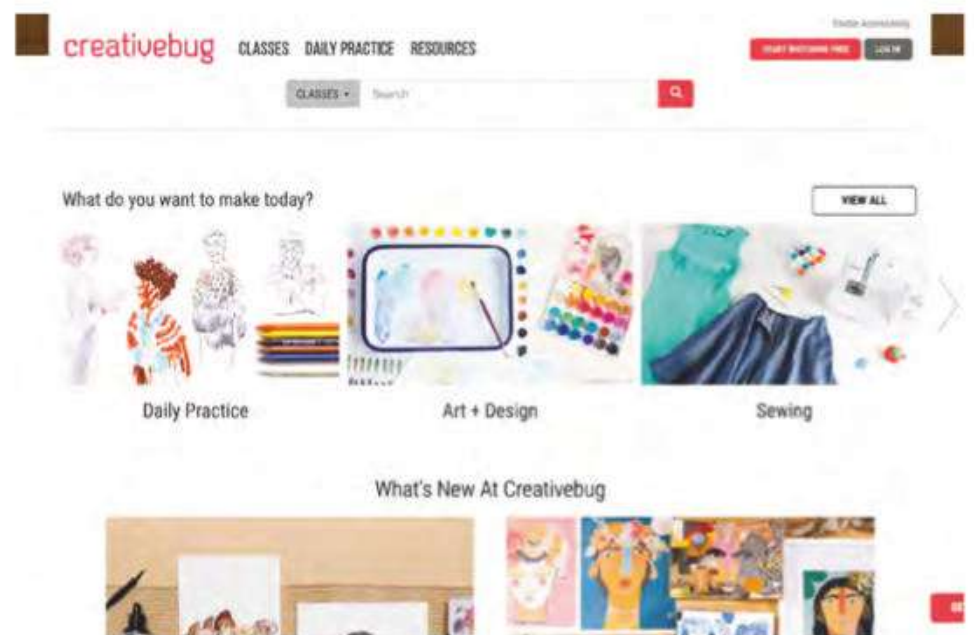
**Price:**  
From \$7.95 per month  
[creativebug.com](http://creativebug.com)

Whatever kind of crafting you want to try your hand at, this video-based site is a great place to learn. It comprises a large collection of craft classes and workshops on a wide variety of topics. Crafts covered include art and design, sewing, quilting, papercraft, knitting, crochet, food and home (including baking and home décor), and jewellery making. There are also special classes for children (in different age ranges) and holiday themes. Each class is divided into video

chapters and comes complete with a description and detailed supplies list, downloadable resources, and even a video transcript. So you should have everything needed to start creating the project, and can discuss it with other users in the

class discussion at the bottom of the description page.

In addition, there's a pattern library and handy collections of related classes. While there's a monthly membership fee, you can start watching for free to try it out. 



## Craft on the web

Learn about crafts with these free online resources



### CRAFT GAWKER

Like a Pinterest for crafts, this site offers a curated photo gallery of project ideas, with links to their sites for instructions so you can try making them.

► [craftgawker.com](http://craftgawker.com)

### BLOSSOM CROCHET

Updated twice weekly, this YouTube channel is a treasure-trove of

project tutorials. If you're a crochet newbie, check out the Absolute Beginner Series playlist.

► [magpi.cc/blossomcrochet](http://magpi.cc/blossomcrochet)

### THE SPRUCE CRAFTS

With a 20-year-strong library of over 4000 projects from a wide range of crafting fields, it's a great place to visit for some ideas for what to make next.

► [thesprucecrafts.com](http://thesprucecrafts.com)



# Wearable Tech Projects

AUTHOR

Sophy Wong

Price:  
£7 (or free PDF)


[magpi.cc/wearableprojects](http://magpi.cc/wearableprojects)

Combine sewing skills with electronics to create some of the cool-looking wearable technology projects featured in this 164-page book from Raspberry Pi Press.

Sophy Wong expertly guides you through the process of making each item. Starting with the basics of sewable circuits and LEDs, you'll work all the way up to building your own wearable controller (complete with feathers!) for an interactive game of Flappy Bird. Other



projects include NFC data cuff-links, a light-up tote bag, a laser-cut NeoPixel necklace, and a 3D-printed jacket mod with LEDs.

Along the way, you'll discover new techniques for working with fabric, find out about the best microcontrollers to use for wearable projects, and learn the basics of the CircuitPython language to program them. 

# The Art of Tinkering

AUTHOR

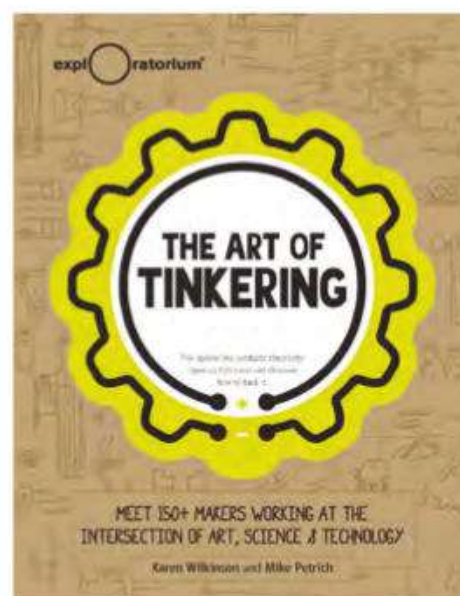
Karen Wilkinson,  
Mike Petrich


Price:  
£24 / \$33

[magpi.cc/tinkeringbook](http://magpi.cc/tinkeringbook)

Akin to a Maker Faire in book form, this beautifully illustrated tome shares the magic of the Exploratorium's Tinkering Studio in San Francisco. While it's more of an inspiring project sampler than a step-by-step guide, it should get your creative juices flowing.

With insights from over 150 makers, you'll learn a lot of useful tips and techniques, while being inspired by a host of impressive projects. These include luminous art installations, squishy circuits using conductive dough, electronic poppable papercraft, wearables and textiles, wire work, cardboard craft, and absurdist automata.



An amazing bonus is that the book's cover is printed with conductive ink that you can use to make a circuit for electronics projects, such as adding a battery and LEDs to it. 

## Maker mine

Useful resources to improve your making skills



### HACKSPACE MAGAZINE

Our sister publication is the place to go for a monthly fix of all things making-related. Learn new techniques for a wide variety of topics, and be inspired by the projects showcased every month.

► [hsmag.cc](http://hsmag.cc)

### MAKERSPACE DIRECTORY

Makerspaces are great places where you can use a range of specialist making equipment. More importantly, you'll meet like-minded people and learn from each other.

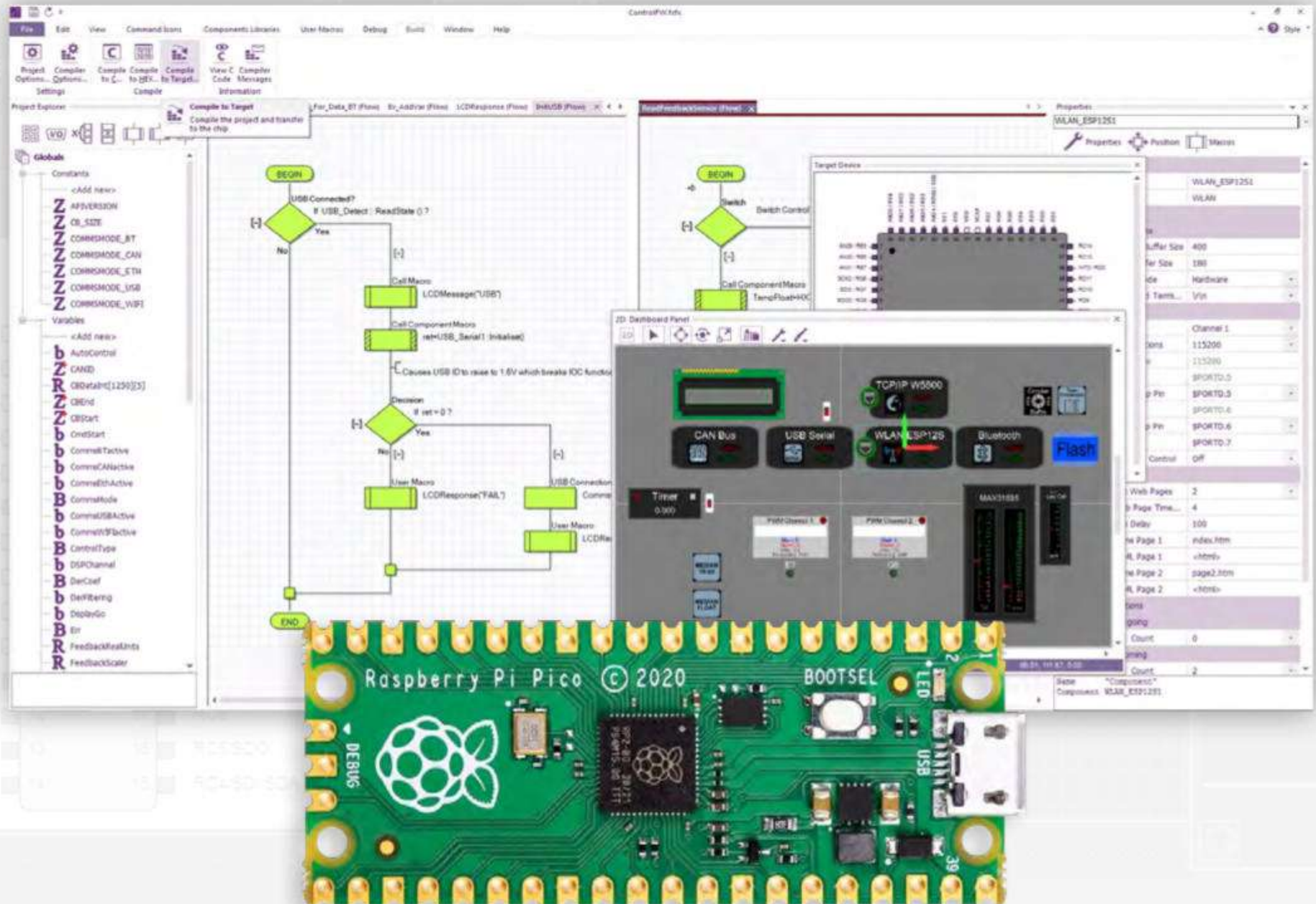
► [makerspaces.make.co](http://makerspaces.make.co)

### HOW TO MAKE EVERYTHING

This weird and wonderful YouTube channel shows how to make various household items from scratch and involves a huge range of making skills. It's fun and you'll learn a lot.

► [magpi.cc/makeeverything](http://magpi.cc/makeeverything)





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# Dr Footleg

Hobby maker, father, STEM Ambassador, and... cave explorer? Dr Footleg has a variety of interests

- Name **Paul Fretwell** | ➤ Occupation **Software engineer**
- Community role **Maker** | ➤ Twitter **@drfootleg**



▲ This chicken coop is fully automated

**L**ike a lot of great nicknames, Dr Footleg is so named because of a simple mishearing of his surname, resulting in a letter addressed to Mr Footleg. After getting his PhD in Chemistry, he upgraded to Dr Footleg.

"I studied science academically, but computers were a hobby right back to my early teens when we got a

C64," Footleg tells us. "When I graduated, I thought working on computers would be something I would enjoy, so I bought a 'teach yourself to program in 21 days' book and started applying for jobs 21 days later! I've always enjoyed designing and making things. It used to be electronics, before creating designs using computers became a thing. After I discovered Raspberry Pi

robots, that rekindled my love of electronics and now I am designing and making my own add-ons for Raspberry Pi."

## When did you learn about Raspberry Pi?

I was quite late discovering Raspberry Pi. I came across an article in Computer Shopper magazine about building a robot. The article used the CamJam EduKit 3, and I bought the kit and a Raspberry Pi Zero to build a robot with my kids. That changed my life, and now I run after-school robotics clubs and build robots to show at Raspberry Jams, to encourage children's interest in STEM subjects.

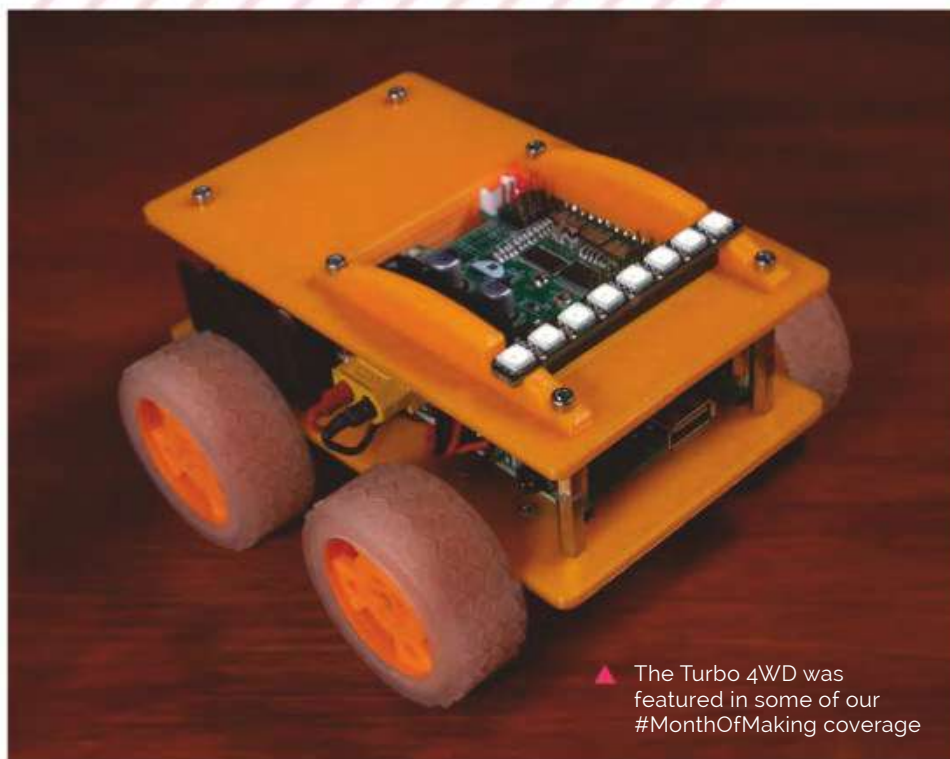
## What was your first Raspberry Pi project?

A CamJam EduKit 3 robot with a Raspberry Pi Zero. From that start, I now have ten Raspberry Pi robots, plus several more built from kits by children in the after-school clubs I've run.

## What's your favourite thing you've made with Raspberry Pi?

My Mars Rover robot which I designed for the Pi Wars 2019





▲ The Turbo 4WD was featured in some of our #MonthOfMaking coverage


“ Now I run after-school robotics clubs and build robots to show at Raspberry Jams ”

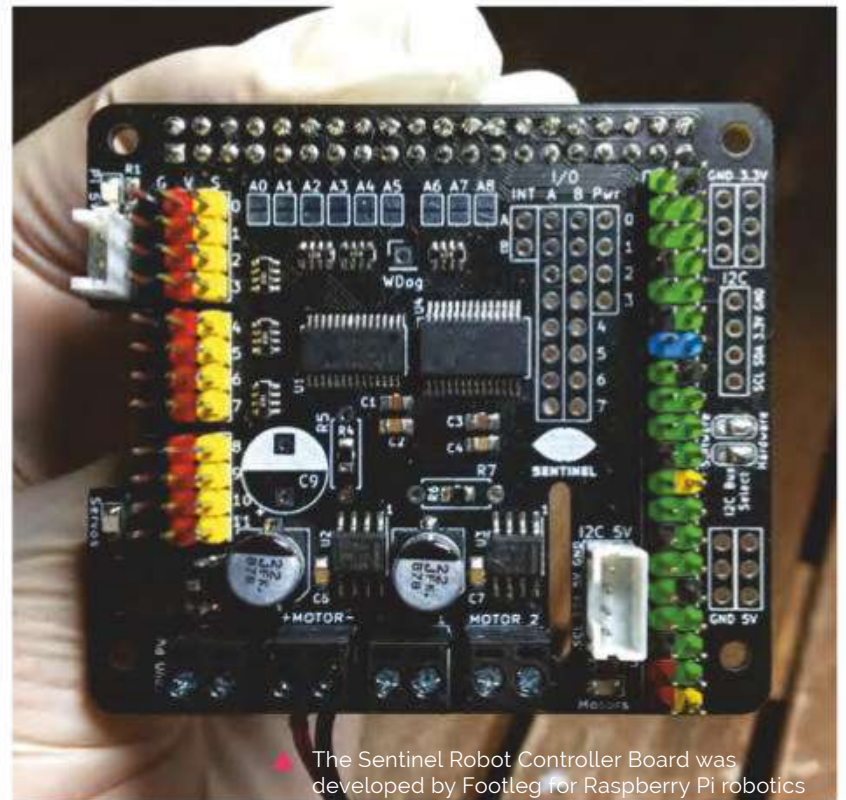
competition. It introduced me to CAD and laser cutting, which I had access to having just joined Makespace Cambridge.

#### Any other hobbies?

Caving is my main other passion. I do exploration and mapping, and underground filming. I am also a caving leader with the Scouts, and help run trips to introduce children to the underground world.

#### Any other projects you'd like to highlight?

Other major projects include a Feather-based lightsaber, and a chicken coop and run I designed and built. In the pipeline, I have an interactive LED cube (based on a Raspberry Pi 4), several PCB projects for robotics and Raspberry Pi power supply, a 3D-printed robot cat, and a walking spider robot. I am also building a Raspberry Pi-based home automation system and sensors which will put the chicken coop online so we can monitor temperature, open and close the door remotely, and see the chickens from the house. 



▲ The Sentinel Robot Controller Board was developed by Footleg for Raspberry Pi robotics



▲ Rocky Rover is a very funky robot and was built for Pi Wars



# MagPi Monday

Amazing projects direct from our Twitter!

**E**very Monday we ask the question: have you made something with a Raspberry Pi over the weekend? Every Monday, our followers send us amazing photos and videos of the things they've made.

Here's a selection of some of the awesome things we got sent this month – and remember to follow along at the hashtag #MagPiMonday!!

01. This little fake Tamagotchi is probably a lot more powerful than one of the originals
02. Hedgehogs are Features Ed Rob's favourite animal, so he was very excited to see this
03. Raspberry Pi Tower – a place where Raspberry Pi folk work, and also this cool tower of Raspberry Pi
04. Flight trackers are a fun way to use Raspberry Pi
05. This little handheld will be a great way for students to test their own games
06. An important race but one Zero 2 W handily wins
07. I wonder if these robots are a little less creepy in motion
08. We love Raspberry Pi-powered puzzle boxes, maybe we should make one...



**Kevin McAleer**  
 @kevsmac

01

This is Pico-tamachibi - a Raspberry pi Pico powered Virtual Pet. Link in bio. #stem #micropython #raspberrypico #pico #robots #robotics #robot #opensource #tamagotchi @themagpi #magpimonday #raspberrypi #smallrobots



10:26 PM · Sep 28, 2021 · Twitter Web App





Jeroen Peters  
@jeroen\_p

02a

Replying to @TheMagPi

Yeah! I created my own powerbank powered "wildlife" cam, so check if the hedgehogs in our garden are still there and if they are actually the ones eating the food we put out for them (and not the cats). Third night, a hedgehog was seen! When I disable Pi's USB, it lasts for 7/8h!



Jon  
@Jontafkasi

03

Replying to @TheMagPi

Added a touch screen to the top pi in my raspberry tower with the intention to create a workplace (at home) music streaming server.



Jeroen Peters @jeroen\_p - Nov 1

02b

Hey @TheMagPi, you wanted to see more hedgehogs?

Powered by Raspberry Pi Zero 2 and better IR support, I present to you the hedgehog-parents.



Philip Shuman  
@ShumanProjects

04

Replying to @TheMagPi and @Raspberry\_Pi

Software update on my rooftop #adsb flight tracker:



youtube.com  
DIY Rooftop Raspberry Pi Aircraft ADS-B Build  
I've built an outdoor ADS-B aircraft position tracker on a budget!



D.D.  
@ODroboticsChick

07

Replying to @TheMagPi

Our family is busy building and updating our #RaspberryPi #python code to get ready for the #robotBlockParty next weekend!



Mark Geri  
@mark\_geri

05

Replying to @TheMagPi

Next Pi Project here is loading RetroPie on a Pi 3B+ with a WaveShare Game hat to make a handheld gaming system that plays student games made on @MSMakeCode

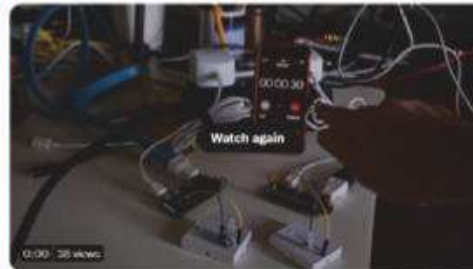


Richard Hayler  
@rthayler

06

Replying to @TheMagPi

We were racing a Pi Zero 2 against a Pi Zero: boot to Desktop and light up an LED. The winner was never in much doubt...



David Pride  
@davejanupride

08

Replying to @TheMagPi

I recused our #RaspberryPi powered treasure chest from campus. Been locked away for almost 2yrs... and still works perfectly. 🎉 #MagPiMonday





# Halloween projects 2021

Other amazing things from the community  
Spooky community builds from  
the scariest night of the year

In issue 111, we showed you how to upgrade your Raspberry Pi projects to be Halloween-ready. Some of our readers already had Halloween plans, and showed us their morbid makes over on Twitter...

01. Ah! We wouldn't want that laughing at us
02. Woah! A startling pumpkin indeed
03. Yargh! The spookiest build this year we've seen so far!
04. Eek! This scary project has been put to use for a good cause
05. Oh! A very cool Halloween costume, even if not very spooky





# Crowdfund **this!** Raspberry Pi projects you can crowdfund this month



## Raspberry Pi Learning Kit

This IOT add-on for Raspberry Pi comes with some Node-RED tutorials – the block/flow code IDE for JavaScript – so that you can get started with it. It has a serial port, PWM motor control, LEDs, and more!

► [kck.st/3Gp6vG7](https://kck.st/3Gp6vG7)



## Oasis-Grow

We featured Oasis-Grow in *The MagPi* in the previous issue, and now the environmental monitoring tool is up for crowdfunding! Whether you have a couple of indoor plants or a more meaty mini-farm, Oasis-Grow has something to offer you.

► [kck.st/3mxVD09](https://kck.st/3mxVD09)

### CROWDFUNDING A PROJECT?

If you've launched a Raspberry Pi-related project, let us know!  
[magpi@raspberrypi.com](mailto:magpi@raspberrypi.com)

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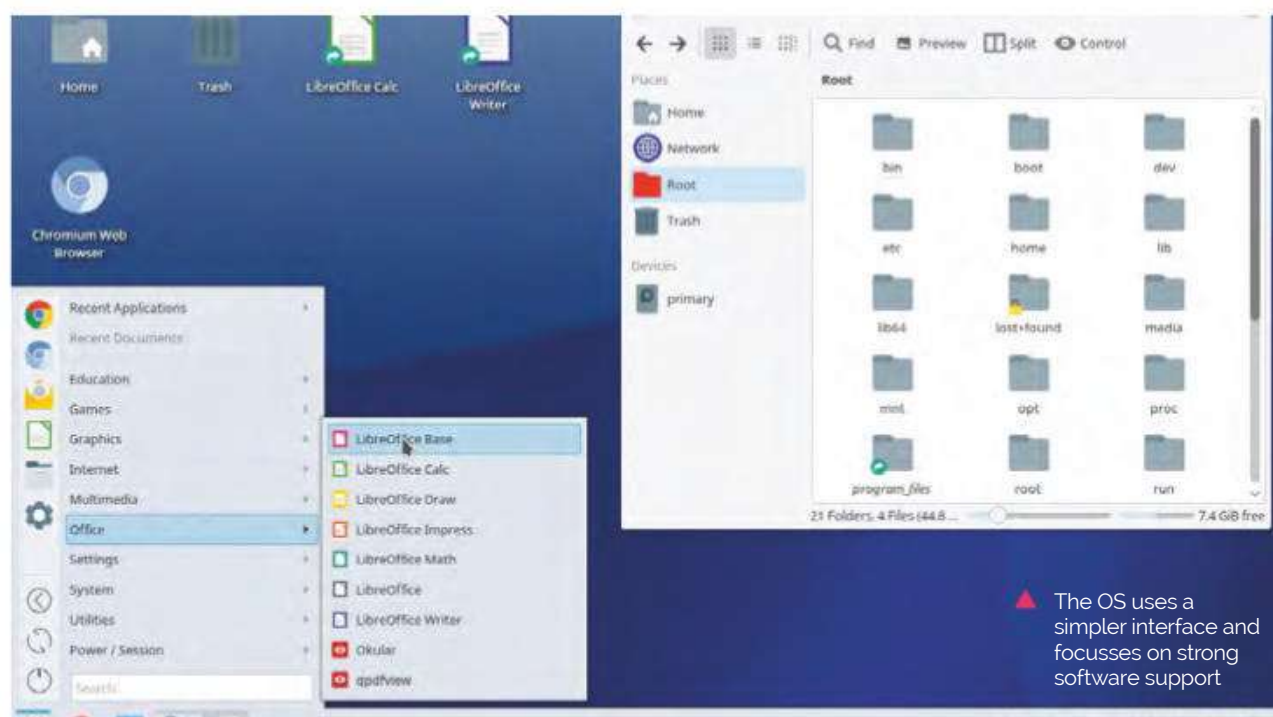
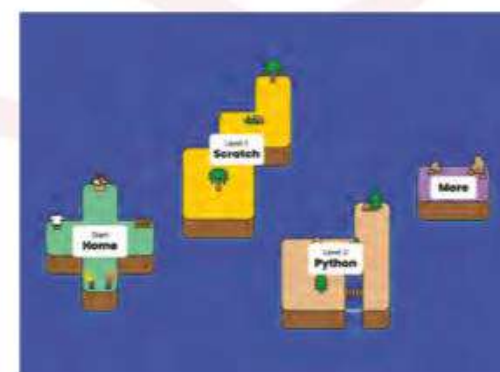
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**XOGO**





# Your Letters



▲ Travel to different islands and create your own robot avatar, all while learning to code

## Code Club at home

**My child is very interested in Code Club but can't actually attend any of them at the moment – I also do not have the skills to actually start one or help them much. Is there any kind of 'Code Club at home' kit that I can get? Otherwise, is there anything else that might help?**

**Cass** via Facebook

Good news, the folks at the Raspberry Pi Foundation have opened Code Club World! It's a more online version of Code Club with its own little gamification activities that make it fun to learn, progress, and show what they've made to friends and family. And it's free! Check it out at [codeclubworld.org](https://codeclubworld.org).

All Code Club projects are available from the Foundation's projects site as well if you'd prefer: [magpi.cc/projects](https://magpi.cc/projects).

## More OS

**Just for your information, as I could not find any mentioning in the recent [operating system] article in *The MagPi* 111, there is yet another Debian derivate for the Raspberry Pi: Q4OS ([magpi.cc/q4ospi](https://magpi.cc/q4ospi)).**

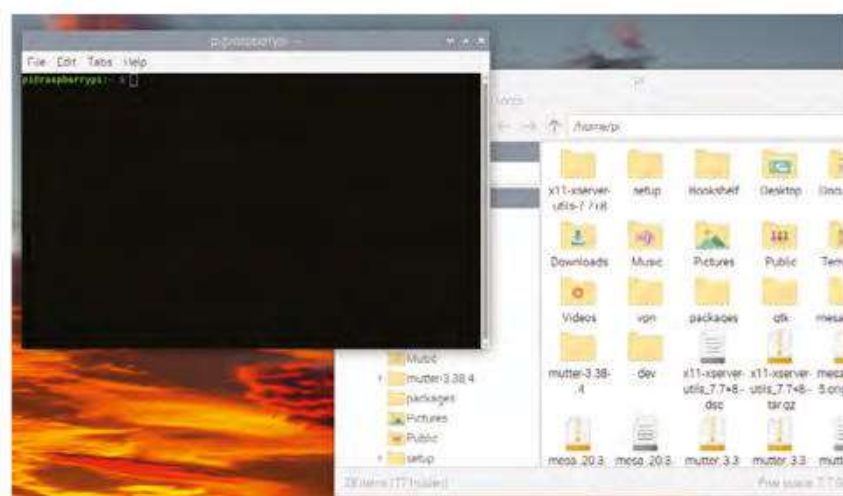
**Bernhard** via email

For those not in the know, Q4OS is a distribution of Linux that aims to offer a classic user interface and only simple accessories and apps. It's great for cloud development as it has low hardware requirements – something Raspberry Pi can be great at.

There are likely other Raspberry Pi operating systems we missed – some are tricky to track down and others aren't aimed at English-speaking audiences, so are much harder for us to review. If there's an OS or spin for Raspberry Pi you think we should know about, let us know!



▼ The new window manager creates nice little visual effects if you have a Raspberry Pi with 2GB or more



### Bullseye benefits

One of my Raspberry Pi systems has been running for a while using the Buster version of Raspberry Pi OS. I'll definitely use Bullseye for future projects, but is there any real reason to update my other Raspberry Pi? It's just a file server.

Alan via Facebook

With every new version of Raspberry Pi OS – and any operating system – comes a lot of little security fixes that are always worth getting if your Raspberry Pi is connected to the internet in any fashion. File servers especially are more open to access, as you are usually accessing them over the internet.

Otherwise, there are loads of updates here and there. GTK+, which is used to create the user interface, has been upgraded to GTK+3. There's also a new window manager, upgraded notifications, and more. Check out the full list of updates on the release blog: [magpi.cc/bullseye](https://magpi.cc/bullseye).

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# WIN ONE OF TEN

## RASPBERRY PI ZERO 2 W AND FLIRC RASPBERRY PI ZERO CASE BUNDLES! IN ASSOCIATION WITH FLIRC

As seen in our Raspberry Pi Zero 2 W overclocking tutorial on page 52, the FLIRC Raspberry Pi Zero Case is the perfect case to keep the processor on Zero 2 cool while you bump up the power.



Head here to enter: [magpi.cc/win](https://magpi.cc/win) | Learn more: [magpi.cc/flirczero](https://magpi.cc/flirczero)

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Competition opens on **25 November 2021** and closes on **16 December 2021**. Prize is offered to participants worldwide aged 13 or over, except employees of the Raspberry Pi Foundation, the prize supplier, their families, or friends. Winners will be notified by email no more than 30 days after the competition closes. By entering the competition, the winner consents to any publicity generated from the competition, in print and online. Participants agree to receive occasional newsletters from The MagPi magazine. We don't like spam: participants' details will remain strictly confidential and won't be shared with third parties. Prizes are non-negotiable and no cash alternative will be offered. Winners will be contacted by email to arrange delivery. Any winners who have not responded 60 days after the initial email is sent will have their prize revoked. This promotion is in no way sponsored, endorsed or administered by, or associated with, Instagram or Facebook.



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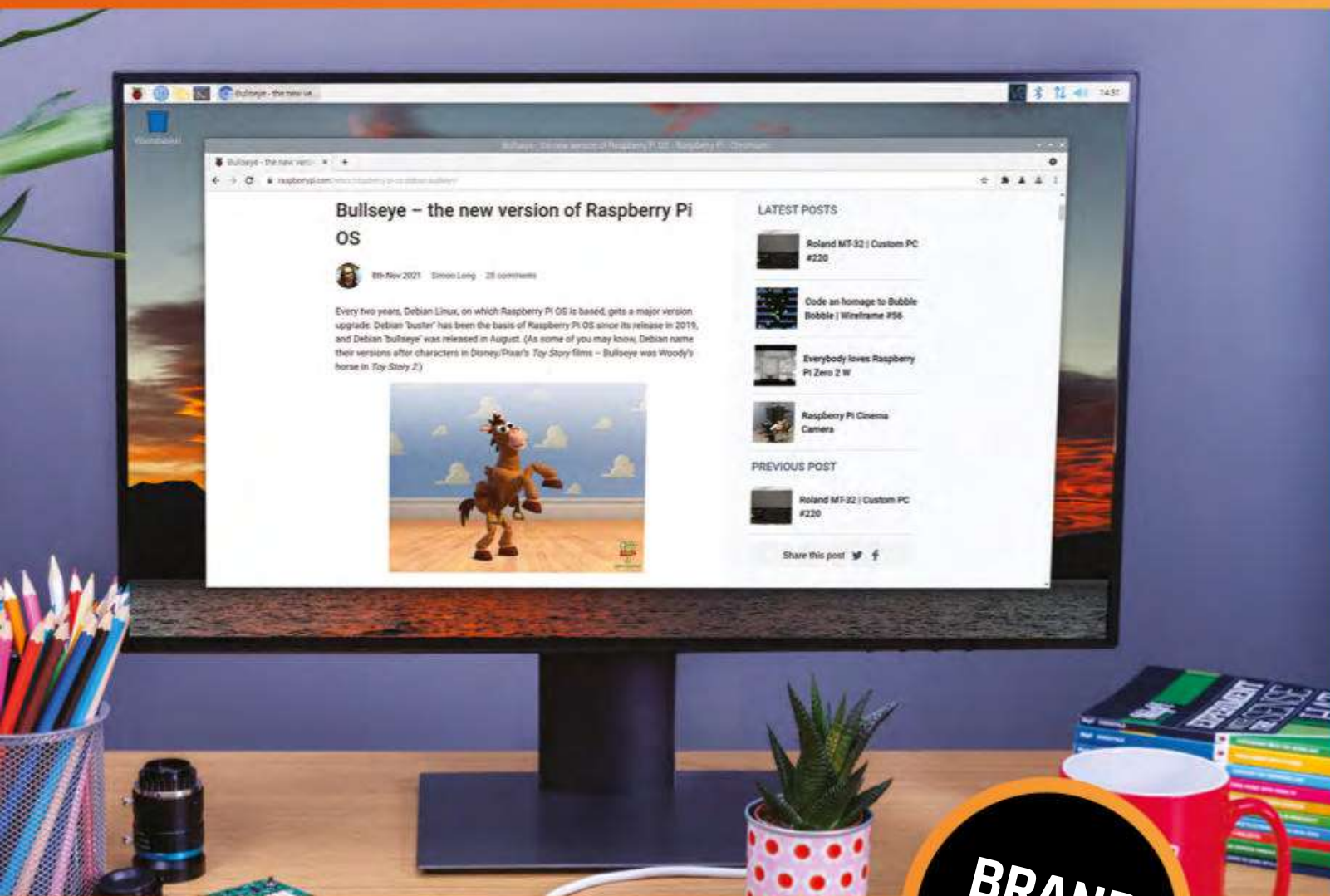


MagPi112





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# Bringing it together

Sitting in the middle of a bunch of makers.

By **Lucy Hattersley**

**I've spent the last few days working with the new Raspberry Pi Build HAT and some bumper packs of bricks kindly supplied.** Like most makers, I loved LEGO® as a kid. Either when following instructions to build Technic trucks or working free-form to build planes, houses, or 'abstract sculptures'.

LEGO hadn't quite become the modern iteration: with its movie tie-ins and themed sets. And it's been interesting to pick up LEGO again at a later age, and discover just how much of it has changed. Mostly for the better.

One thing I love about Build HAT is that it bridges the gap between Raspberry Pi the computer, and learning to code with Raspberry Pi. This is the intersection where *The MagPi* sits.

Many people don't know that Raspberry Pi is two different organisations. There's Raspberry Pi, which designs and makes the computers, and components like the Build HAT. And there's the Raspberry Pi Foundation, the charity that works to put physical computing in the hands of people all over the world. It runs the network of clubs and events and provides computer science courses and curriculum materials to students and teachers, and the Isaac

Computer Science platform (funded by the DfE's National Centre for Computing Education programme.) It also makes a huge range of educational projects, which you will occasionally find in *The MagPi*.

The Build HAT is one of those fantastic products with a foot in both camps. Raspberry Pi Trading can be

**“Twelve-year-old me would have loved this”**

rightly proud of developing such a fantastic product, and the Raspberry Pi Foundation is using Build HAT to create incredible learning experiences for children (of all ages). Adding the computing power of Raspberry Pi to control LEGO with Python is sublime. I keep thinking 'Twelve-year-old me would have loved this.'


Still, you don't have to be twelve years old to love LEGO. Frankly, you can improve your coding skills at any age, so why not have fun with bricks while you're at it?

## Engineering success

There's another intersection at work in *The MagPi*. On the one side of a Venn diagram are the learners, the makers, and hobbyists; and on the other the engineers, developers, and professional 'doers'.

*The MagPi* magazine has always tried to sit in the middle of this tribe. And I'm not wholly convinced they are that separate. After all, today's hobbyist maker is tomorrow's professional developer. And most people who work with computers enjoy computers on the side. You never stop learning.

The engineering side of Raspberry Pi is growing, and we are increasingly coming across projects with a professional bent. I looked at the Midas display screen this month and realised just how often I see screens in stores, transport hubs, and on the streets. A huge number of them moving forward are going to be powered by Raspberry Pi. Modern manufacturing facilities, storage areas, and delivery trucks are packed with sensors feeding back data on heat, movement, and location. The low-cost, low-energy requirements, and stable Linux support of Raspberry Pi make it perfect for these uses.

Wherever you are in your Raspberry Pi journey, you can be sure *The MagPi* magazine will make every effort to be there with you. 

**AUTHOR**

**Lucy Hattersley**

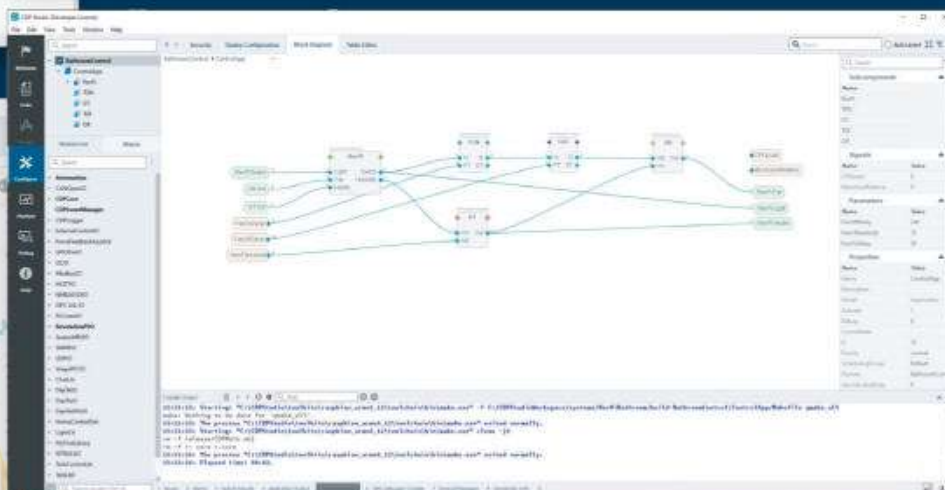
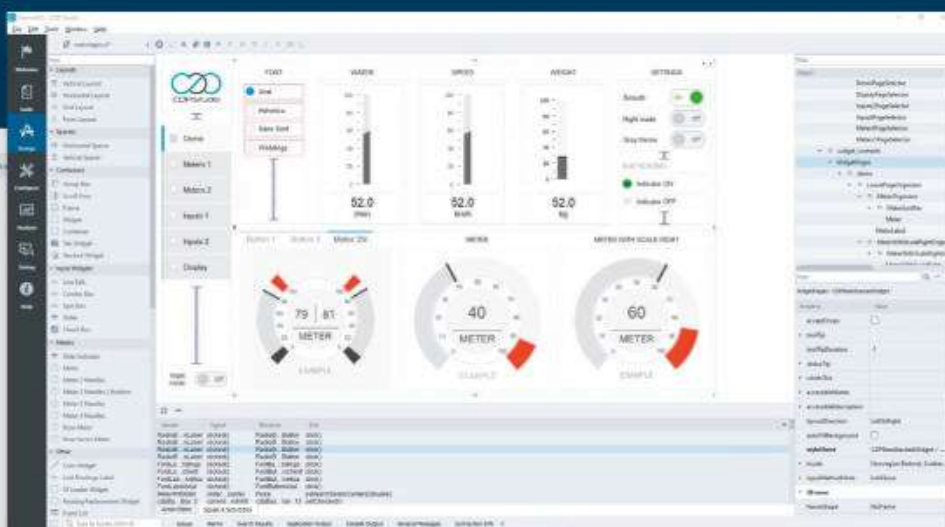
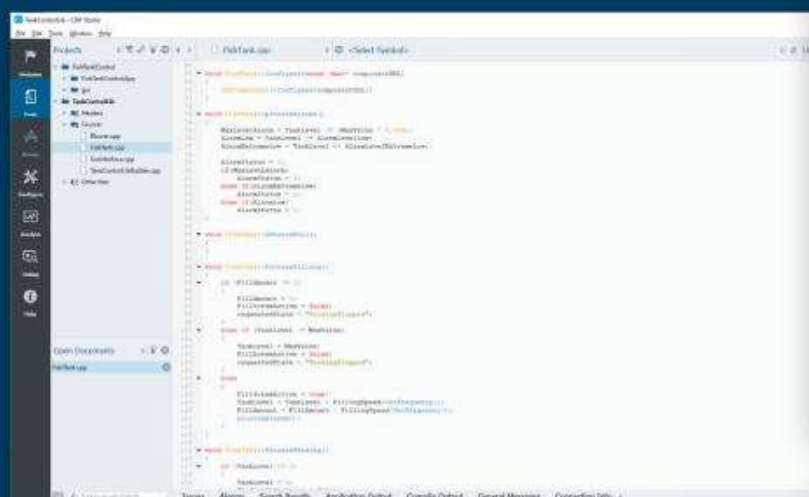
Lucy is editor of *The MagPi* and is hassling her cat with various brick-themed endeavours.

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